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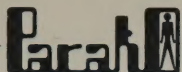
PARAHO OIL SHALE DEMONSTRATION

MINING OPERATIONS

FINAL REPORT
VOLUME 2

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Under a lease approved in May, 1972, Paraho Corporation, a private company, entered into an agreement with the federal government to conduct a demonstration of the Paraho processes and hardware for the production of shale oil. This final Report to participants in the demonstration is a six-volume series.

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PARAHO OIL SHALE DEMONSTRATION

MINING OPERATIONS

FINAL REPORT

THIS VOLUME IS A FINAL REPORT OF THE PARAHO OIL SHALE DEMONSTRATION, A PROJECT OF THE PARAHO OIL SHALE RESEARCH FACILITIES, INC., A PRIVATE COMPANY, ENTERED INTO AN AGREEMENT WITH THE FEDERAL GOVERNMENT TO CONDUCT A DEMONSTRATION OF THE PARAHO PROCESSES AND HARDWARE FOR THE PRODUCTION OF SHALE OIL.

CORPORATION, 300 ENTERPRISE BUILDING, GRAND JUNCTION, COLORADO 81501.

OVER, PARAHO OIL SHALE RESEARCH FACILITIES, INC., A PRIVATE COMPANY, ENTERED INTO AN AGREEMENT WITH THE FEDERAL GOVERNMENT TO CONDUCT A DEMONSTRATION OF THE PARAHO PROCESSES AND HARDWARE FOR THE PRODUCTION OF SHALE OIL.

PUBLISH INFORMATION FOR THE PARAHO OIL SHALE RESEARCH FACILITIES, INC., A PRIVATE COMPANY, ENTERED INTO AN AGREEMENT WITH THE FEDERAL GOVERNMENT TO CONDUCT A DEMONSTRATION OF THE PARAHO PROCESSES AND HARDWARE FOR THE PRODUCTION OF SHALE OIL.

BE STRICTLY CONFIDENTIAL AND NOT TO BE DISCLOSED TO THE PUBLIC OR TO ANY OTHER PERSON OR ORGANIZATION WITHOUT THE WRITTEN PERMISSION OF THE PARAHO OIL SHALE RESEARCH FACILITIES, INC., A PRIVATE COMPANY, ENTERED INTO AN AGREEMENT WITH THE FEDERAL GOVERNMENT TO CONDUCT A DEMONSTRATION OF THE PARAHO PROCESSES AND HARDWARE FOR THE PRODUCTION OF SHALE OIL.

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Prepared

By

THE CLEVELAND-CLIFFS IRON COMPANY

DEVELOPMENT ENGINEERING, INC.

For

PARAHO OIL SHALE DEMONSTRATION, INC.

300 Enterprise Building

Grand Junction, Colorado 81501

July 1976

The field operations were conducted at the Small Volume Oil Shale Research Facilities located at the Small Oil Shale Reserves near Rifle, Colorado. On these leased facilities was a Grand Junction, Colorado 81501 line (BOM) to the Energy Research and Development Administration (ERDA) when the latter agency was formed in 1974.

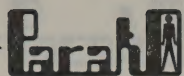
The Paraho Oil Shale Demonstration was privately sponsored by the following seventeen participants at a total cost of \$9.4 million:

Schrie Petroleum Company

Southern California Edison Company

The Cleveland-Cliffs Iron Company

Gulf Oil Corporation



FOREWORD

Under a lease approved by the President of the United States in May, 1972, Paraho undertook, in cooperation with the federal government, to demonstrate the engineering, economic and environmental feasibility and desirability of the Paraho processes and hardware for retorting oil shale. This Final Report to participants of the Paraho Oil Shale Demonstration is a six-volume document that describes the research and development operations, the engineering design and cost estimating, and the commercial evaluation studies carried out from late-1973 to mid-1976.

THIS VOLUME 2 IS CONSIDERED CONFIDENTIAL UNDER THE TERMS OF THE PARTICIPANTS AGREEMENTS WITH PARAHO CORPORATION AND DEVELOPMENT ENGINEERING, INC. MORE-OVER, BECAUSE OF THE COMMITMENT TO THE GOVERNMENT NOT TO PUBLISH INFORMATION PREMATURELY, DISTRIBUTION SHOULD BE STRICTLY CONTROLLED ON A NEED-TO-KNOW BASIS UNTIL AFTER THIS MATERIAL HAS BEEN PUBLISHED BY THE GOVERNMENT OR PARAHO.

The field operations were conducted at the Anvil Points Oil Shale Research Facilities located on the Naval Oil Shale Reserves near Rifle, Colorado. Administration of these leased facilities was transferred from the Bureau of Mines (BOM) to the Energy Research and Development Administration (ERDA) when the latter agency was formed in 1974.

The Paraho Oil Shale Demonstration was privately sponsored by the following seventeen participants at a total cost of \$9.4 million:

Sohio Petroleum Company
Southern California Edison Company
The Cleveland-Cliffs Iron Company
Gulf Oil Corporation

FOREWORD

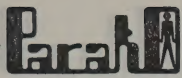
Under a lease approved by the President of the United States in May, 1971, Paraho Corporation, in cooperation with the Federal Government, to demonstrate the engineering, economic and environmental feasibility and desirability of the Paraho process and hardware for recovering oil shale. This final report to participants of the Paraho Oil Shale Demonstration is a six-volume document that describes the research and development operations, the engineering design and cost estimating, and the commercial evaluation studies carried out from 1969-1971 to 1971-1972.

THIS VOLUME 1 IS CONSIDERED CONFIDENTIAL UNDER THE TERMS OF THE PARTICIPANTS AGREEMENTS WITH PARAHCO CORPORATION AND DEVELOPMENT ENGINEERING, INC. MOREOVER, BECAUSE OF THE COMMITMENT TO THE GOVERNMENT NOT TO FURNISH INFORMATION PREVIOUSLY, DISTRIBUTION SHOULD BE STRICTLY CONTROLLED ON A NEED-TO-KNOW BASIS UNTIL AFTER THIS MATERIAL HAS BEEN FURNISHED BY THE GOVERNMENT OF PARAHCO.

The field operations were conducted at the Naval Point Oil Shale Research Facility located on the Naval Oil Shale Reserve near Rifle, Colorado. Administration of these leased facilities was transferred from the Bureau of Mines (BOM) to the Energy Research and Development Administration (ERDA) when the latter agency was formed in 1974.

The Paraho Oil Shale Demonstration was privately sponsored by the following seven participants at a total cost of \$2.4 million:

Shell Petroleum Company
Southern California Edison Company
The Cleveland-Cliffs Iron Company
Gulf Oil Corporation



Arthur G. McKee and Company

Kerr-McGee Corporation

Shell Development Corporation

Standard Oil Company (Indiana)

The Carter Oil Company (Exxon)

Mobil Research and Development Corporation

Webb-Gary-Chambers-McLoraine (Group)

Sun Oil Company

Texaco Inc.

Phillips Petroleum Company

Atlantic Richfield Company

Marathon Oil Company

Chevron Research Company

These participants received the right to license Paraho's oil shale technology on favorable terms for their support and cooperation which are gratefully acknowledged.

The results of Paraho's operations at Anvil Points are encouraging. They demonstrate that the process works, that the equipment is operable and durable, that thermal efficiencies and yields are high, and that the entire system developed is environmentally acceptable. The extended periods of Paraho retort operations and the results obtained demonstrate this. The evidence includes the 77-day Pilot Plant run and the 56-day Semi-Works run, both of which were terminated voluntarily.

After the 56-day retort run, 10,000 barrels of Paraho crude shale oil were shipped to the nearby Gary Western Refinery and converted into military products. This federally funded work was done for the U.S. Navy's Energy and Natural Resources Research and Development Office. That Office coordinated the refining and the nationwide, refined product testing program and publishing a report entitled:

Arthur G. McKee and Company
Kerr-McGee Corporation
Shell Development Corporation
Standard Oil Company (Indiana)
The Carter Oil Company (Texas)
Mobil Research and Development Corporation
Webb-Gary-Chambers-McLaurin (Group)
Sun Oil Company
Texaco Inc.
Phillips Petroleum Company
Atlantic Richfield Company
Marathon Oil Company
Chevron Research Company

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The results of Paraho's operations at Navajo Point are encouraging. They demonstrate that the process works, that the equipment is operable and durable, that thermal efficiency and yields are high, and that the entire system developed is environmentally acceptable. The extended periods of Paraho resort operations and the results obtained demonstrate this. The evidence includes the 77-day Pilot Plant run and the 56-day Semi-Works run, both of which were terminated voluntarily.

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Production and Refining of 10,000 Bbl. Paraho Crude
Shale Oil Into Military Fuels, U. S. Navy Contract
#N0014-75-C-0055

A retorted shale management research project jointly funded by the Bureau of Mines and Paraho will be completed in late-1976 at an estimated additional cost of \$0.5 million. At that time, a report entitled, "Retorted Shale Management", will be issued as the concluding volume of this report.

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Paraho

Production and Refining of 10,000 Bbl. Paraho Crude
Shale Oil Into Military Fuels, U. S. Navy Contract
#W0014-75-C-0052

A reformed shale management research project jointly funded by the Bureau of Mines and Paraho will be completed in late-1976 at an estimated additional cost of \$0.5 million. At that time, a report entitled, "Reformed Shale Management", will be issued as the concluding volume of this report.

PARAHO OIL SHALE DEMONSTRATION

MINING OPERATIONS

FINAL REPORT

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5.5.5 Ventilation

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- 5.4 Joy Drill and Bit Test
- 5.5 Man/Machine Work Studies
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 - 5.5.2 Chasing and Blasting
 - 5.5.3 Scaling
 - 5.5.4 Rock Bolting
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 - 5.5.6 Truck Loading and Hauling

1. INTRODUCTION

The Cleveland-Cliffs Iron Company (Cliffs), one of the initial participants in the Paraho Oil Shale Demonstration, provided Development Engineering, Inc. (DEI) with preliminary mine plans and costs to develop the demonstration program at Anvil Points. Initially, DEI planned to subcontract only the mining for the project to Cliffs. This would have included mining equipment maintenance which Cliffs was well qualified to perform. In the interest of efficiency, it was decided to add all maintenance to Cliffs responsibilities under DEI's management supervision. Since this gave Cliffs responsibility for most labor procurement, rather than duplicate labor personnel services, Cliffs was requested to handle the procurement of operating labor as well. This labor operated under DEI's direct supervision.

Cliffs and DEI worked together to obtain the necessary approvals and permits for mine startup. This report deals only with mining operations.

Two areas, adjacent to the U. S. Bureau of Mines' (U.S.B.M.) Demonstration Mine, had been investigated as potential locations for the new mining effort. One plan envisioned extraction of shale from an area immediately east of the Demonstration Mine, utilizing #3 portal as access. A second plan proposed

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mining an area to the north, using #1 portal and Able Drift as a means of entry. The second plan was selected to supply ore for the project because of lower preproduction cost, easier access to the zone of interest, and reduced ventilation problems (see Figure 1-1).

Between August, 1974, and December, 1975, a total of 101,490 tons of oil shale were mined for processing. The shale, after crushing and screening, was used as feed for the Paraho retort. Mine preproduction work had been started in mid-January, 1974. Activity at the mine, except for some hauling of stockpiled material, ceased on December 15, 1975.

The primary function of the mining effort was to supply oil shale for the Paraho Oil Shale Demonstration. However, during the period, Man/Machine Work Studies of all mining functions were made and several types of drill equipment and a mechanical scaler were tested for their applicability to oil shale mining. An evaluation study to determine the percent of $-\frac{1}{2}$ " product resulting from blasting and crushing oil shale to $-3" + \frac{1}{2}"$ was conducted also. Detailed reports of work studies of individual mining functions and equipment testing are included in the Appendix.

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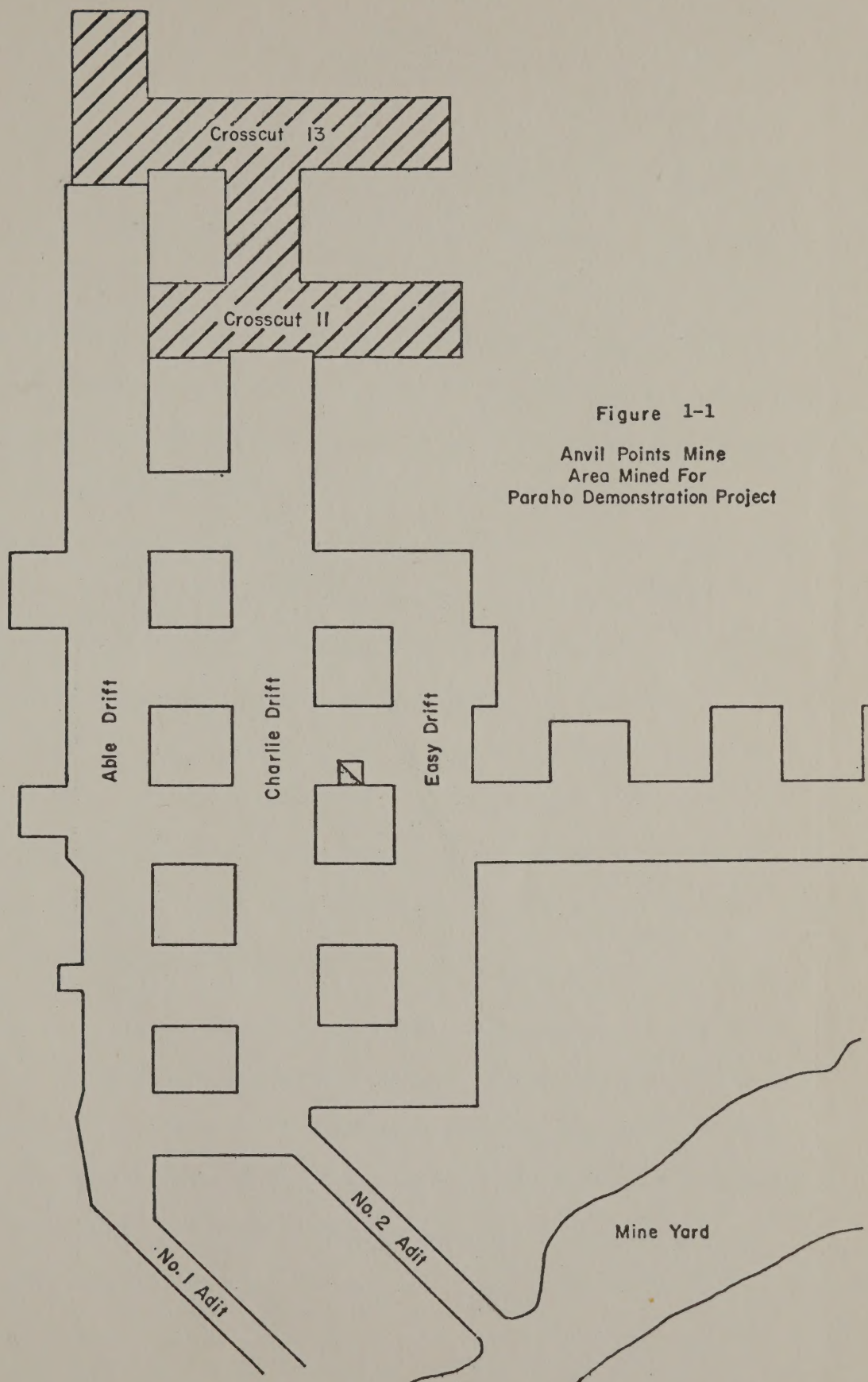
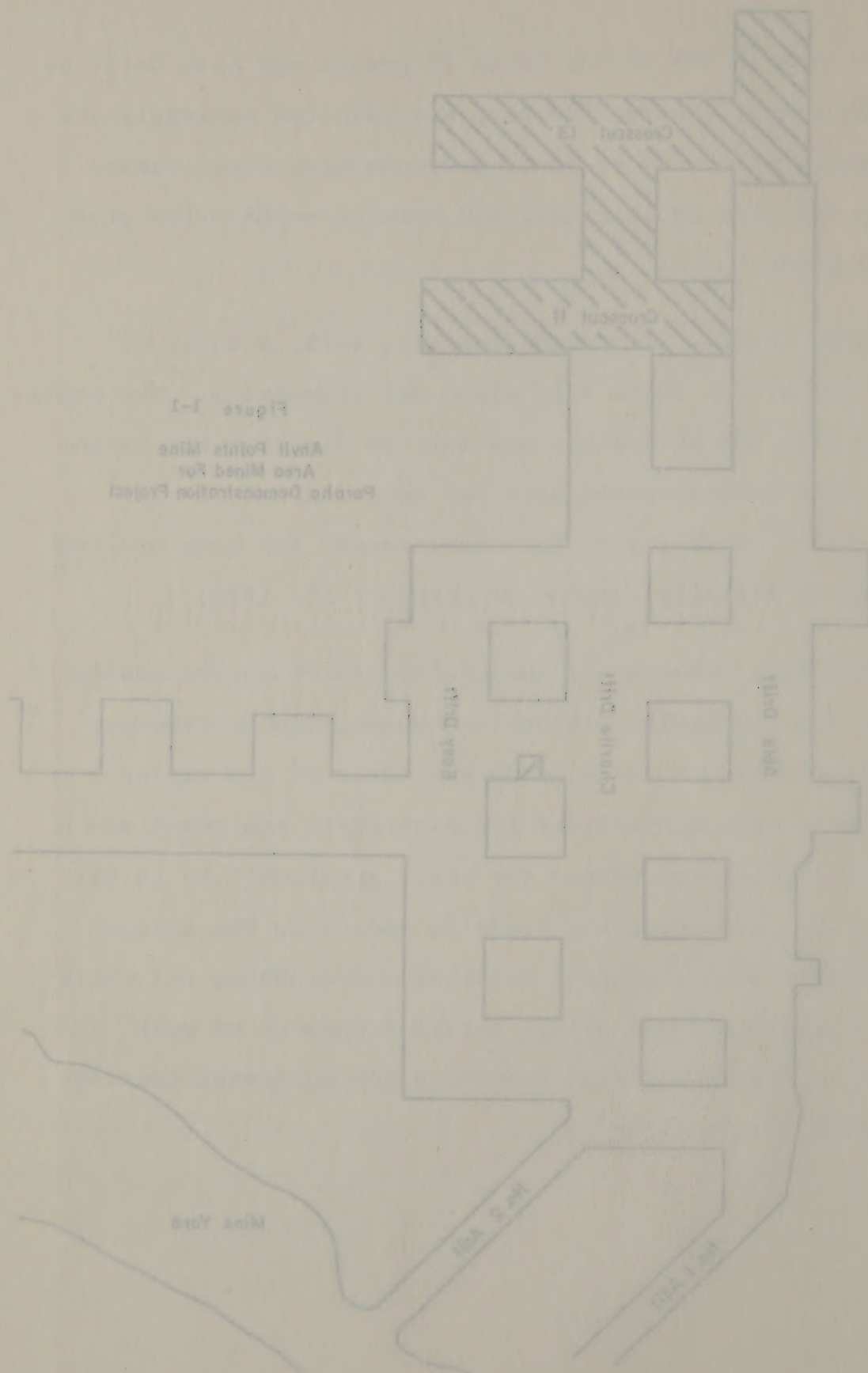


Figure 1-1
Anvil Points Mine
Area Mined For
Paraho Demonstration Project

Figure 1-1
 Area Mine for
 Pointe Demonstration Project



2. PREMINING ACTIVITY

3. PRODUCTION MINING

**4. INDUSTRIAL
ENGINEERING**

5. APPENDIX

2. PREMINING ACTIVITY

2.1 Roof Examination and Control

Prior to final acceptance of Able Drift as an access way into the mining area, the roof over the entry was carefully inspected. Jointing and fractures were mapped. Comparisons made with similar information, compiled by the U.S.B.M. team years before, showed that little change had taken place. Inspection of five old stratiscope holes and comparison with Bureau's records indicated only minimal changes in roof strata partings had occurred. Sagmeters, that had been placed in the roof ten years earlier, were checked. Here too, readings compared favorably with those on record, reemphasizing the stable condition of the mine roof. As a final precaution, seven core holes, 25 to 30 feet deep, were drilled into the roof over Able Drift at approximate 120 foot intervals. Core from these holes showed the roof rock to be competent and parting frequency to be within acceptable limits.

After ascertaining roof stability, miners were assigned the task of roof control improvement. The roof bolts in Able Drift were checked with a torque wrench and retightened, as needed, to provide maximum effectiveness. Since existing bolts were widely spaced, additional bolts were installed to obtain a five foot by five foot spacing pattern.

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Approximately 800 additional roof bolts were placed as a precautionary roof control measure. Loose rock was scaled from the roof and ribs as the bolting operation proceeded from the portal toward the new mining area.

2.2 Mine Road Repair

The road between the mine and the crushing plant is 5.2 miles long. Four hairpin switchbacks are located along its upper portion. Much of the gradient is at -10% as the travel way descends from the mine elevation of 8,200 feet to the plant at 6,000 feet above sea level. Prior to plant startup, many spots along the road were found to be too narrow to accommodate the 50 ton trucks being scheduled for use on the oil shale haul.

Several of the narrow spots were made usable by simply dozing and ripping material from the inside near vertical banks. One stretch required drilling and blasting to accomplish this end. In several areas, steel piling was driven along the outer edge of the roadway to support cribbing and fill, thus extending the road shoulders by six feet or more. A number of culverts were extended to prevent washing of replaced shoulder fill. After the repair work was completed, the entire road received a top dressing of crushed river gravel and crushed oil shale.

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Several of the narrow spots were made usable by simply boring and rigging material from the inside near vertical banks. One stretch required drilling and blasting to accomplish this end. In several areas, steel piling was driven along the outer edge of the roadway to support clip-ping and fill, thus extending the road shoulders by six feet or more. A number of culverts were extended to prevent washing of replaced shoulder fill. After the repair work was completed, the entire road received a top dressing of crushed river gravel and crossed oil shale.

The improved road still did not meet the new State and Federal safety standards set for elevated mine roadways. To be in full compliance, run outs were needed at each switchback and outside shoulders required berms or guardrails. The road was not wide enough to berm and to make it so, would require complete rebuilding. Berms or guardrails would, in addition, interfere with snow removal efforts and, due to physical limitations at switchback locations, run outs could not be constructed unless major amounts of money were committed. A variance permitting use of the road, without further modification, was applied for and received prior to plant startup.

2.3 Mine Equipment Acquisition

Specialized equipment needed to activate the mine acquired in the months preceding actual mine startup. A need to minimize the cost of mining oil shale for the Paraho project resulted in considerable "shopping" to obtain the required machinery.

2.3.1 Usable equipment left from the U. S. Bureau of Mines' activities at Anvil Points included a compressor, two water trucks, an aerial platform, and two motor graders. These were renovated by the maintenance group. The aerial platform was modified for use as an explosives loader.

The improved road still did not meet the new State and Federal safety standards set for elevated mine roadways. To be in full compliance, run outs were needed at each switchback and outside shoulders required berms or guard-rails. The road was not wide enough to berm and to make it so, would require complete repaving. Berms or guard-rails would, in addition, interfere with snow removal efforts and, due to physical limitations at switchback locations, run outs could not be constructed unless major amounts of money were committed. A variance permitting use of the road, without further modification, was applied for and received prior to plant startup.

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2.3.2 A drill jumbo, equipped for rotary drilling, was rented from the Colony Development Operation. The single boomed rig had been used in the Mobil Mine before being purchased by Colony.

2.3.3 A used Gradall mechanical scaler was located in Boise, Idaho and purchased for the project.

2.3.4 Two 50 ton capacity Hough 350 Payhaulers and a Hough six yard 560 Payloader were purchased new for the loading and hauling functions. The Payhauler's four-wheel drive feature was felt to be of benefit because of adverse haul conditions between mine and plant.

2.3.5 A roof bolter, ventilation fan and semi-portable substation were purchased from the Mobil Mine group.

2.4 Other Premining Activities

Prior to mine startup, the 100,000 cfm mine fan and approximately 800 feet of six foot diameter tubing were installed to provide ventilation to the mining area. An 800 cfm compressor was installed in Crosscut #6 and an electrical substation was set up in Crosscut #8. Air and water were piped to the mining faces. Power lines were hung, as needed, to points of usage.

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Early in the program, several attempts were made to re-activate a system that had supplied water to the mine from reservoirs located on the mesa above the mine. The efforts included dam repair and equipment replacement. Ultimately, the project was abandoned when it became apparent that the ponds would require dredging. Throughout the period of mine activity, water, required by the mining operation, was hauled from the plant.

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3. PRODUCTION MINING

**4. INDUSTRIAL
ENGINEERING**

5. APPENDIX

3. PRODUCTION MINING

3.1 Mining Function Description

3.1.1 Drilling: Face drilling was handled by a Gardner-Denver Prototype, single boomed jumbo. Drilling action was straight rotary. The machine was capable of drilling 30 foot deep blastholes, though most drilling in the program was limited to holes less than 25 feet in depth. The standard drill pattern consisted of a V-cut round of 26 4- $\frac{1}{4}$ " diameter holes in a mine face that was 55 feet wide and 40 feet high (see Figure 3-1). The drill rounds blasted during the program pulled an average depth of 18.2 feet and produced 2,670 tons.

3.1.2 Charging and Blasting: Blasthole charging utilized an ammonium nitrate and fuel oil mixture as a primary blasting agent. The AN/FO was pneumatically blown into holes from a pressure pot of 400 pounds capacity. Blasters worked from an elevating platform to charge holes in the 40 foot high faces.

Special charging techniques were practiced when loading rib holes. Two inch cardboard tubes, placed in the holes, were filled with AN/FO, leaving an uncharged space between the tube and the wall of the

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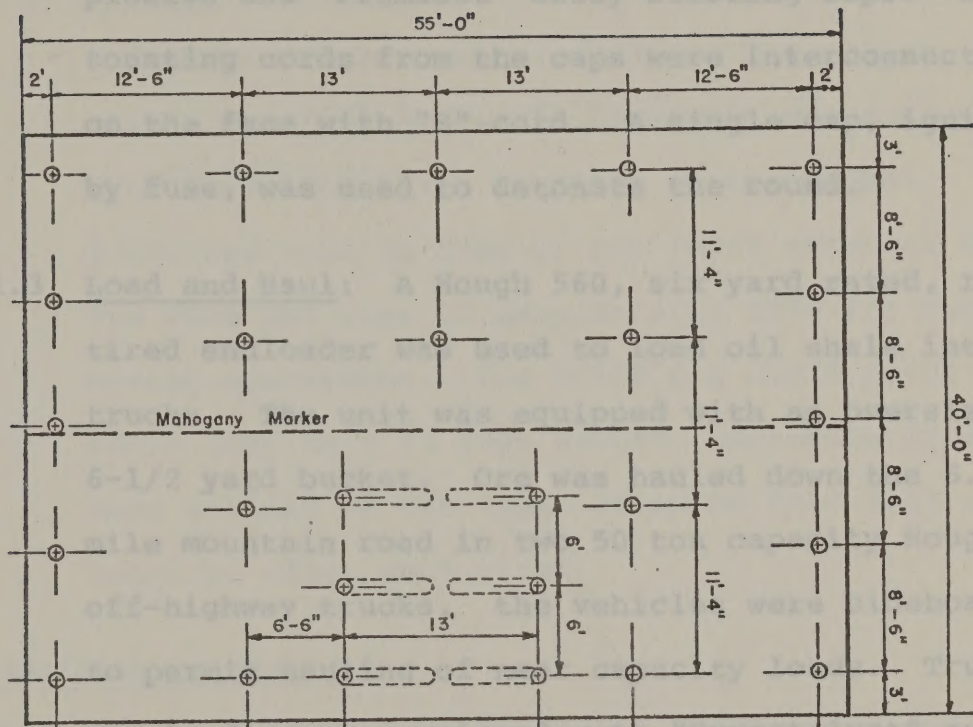
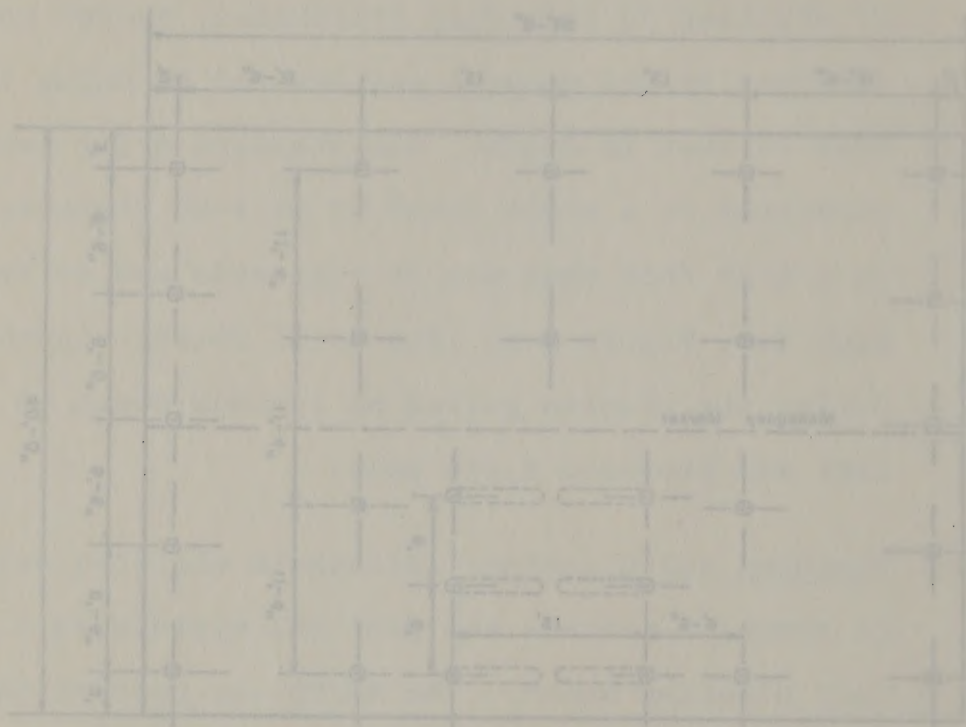


Figure 3-1

Typical 26 Hole Pattern
Anvil Points Mine



Typical 20' x 20' Floor

See Notes

hole. The effect was twofold. Both the reduced amount of explosive and the air cushion around the explosive column tended to reduce blast damage to the pillars.

All blastholes were primed with a high strength explosive and "Primadet" delay blasting caps. Detonating cords from the caps were interconnected on the face with "E" cord. A single cap, ignited by fuse, was used to detonate the round.

3.1.3 Load and Haul: A Hough 560, six yard rated, rubber tired endloader was used to load oil shale into trucks. The unit was equipped with an oversized 6-1/2 yard bucket. Ore was hauled down the 5.2 mile mountain road in two 50 ton capacity Hough 350, off-highway trucks, the vehicles were sideboarded to permit hauling of near capacity loads. Trucks and loader were equipped with "Oxycatalyst" exhaust conditioners to permit operation within the mine.

3.1.4 Roof Bolting: The mine roof was roof bolted as it was exposed. Bolts, six and seven feet in length, were installed in a grid pattern on approximate five foot centers after each round was mucked out. Bolts were torqued to approximately 150 foot-pounds

hole. The effect was twofold. Both the reduced amount of explosive and the air cushion around the explosive column tended to reduce blast damage to the pillars.

All blastholes were primed with a high strength explosive and "Primadex" delay blasting caps. Detonating cords from the caps were interconnected on the face with "E" cord. A single cap, ignited by fuse, was used to detonate the round.

3.1.3 Load and Haul: A Hough 260, six yard rated, rubber

lined endloader was used to load oil shale into trucks. The unit was equipped with an oversized 6-1/2 yard bucket. Ore was hauled down the 350 mile mountain road in two 50 ton capacity Hough 350 off-highway trucks, the vehicles were sideboarded to permit hauling of near capacity loads. Trucks and loader were equipped with "Oxycatlyst" exhaust conditioners to permit operation within the mine.

3.1.4 Roof Bolting: The mine roof was roof bolted as it

was exposed. Bolts, six and seven feet in length, were installed in a grid pattern on approximately five foot centers after each round was mucked out. Bolts were torqued to approximately 150 foot-pounds

as they were installed. Roof bolting was accomplished from an elevating platform equipped with a single Gardner-Denver D93HR drill machine. This hydraulically rotated drill was used to drill bolt holes and tighten the roof bolts.

3.1.5 Scaling: Rib and face scaling was accomplished with a Gradall 600 mechanical scaler. The scaler, actually a modified hydraulic backhoe, was equipped with a scaling tooth in place of the bucket. The tooth was used to rake or pry loose material from the face and ribs to make an area safe for subsequent mining operations. The G-600 rig could reach and scale only to a 37 foot height, consequently some hand scaling of the upper three or four feet was required after each blast.

3.2 Production Statistics

The first round taken from the Anvil Points mine during the Paraho Project was blasted August 7, 1974. The final heading was shot on November 26, 1975. In all, 38 full rounds were shot in the campaign, advancing headings and crosscuts a total of 692 feet. Other statistics are as follows:

- o Total mined 101,490 tons
- o Advance per round 18.2 Feet

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plished from an elevating platform equipped with a
single Gardner-Denver D33M drill machine. This
hydraulically rotated drill was used to drill bolt
holes and tighten the roof bolts.

3.1.2 Scaling: Rib and face scaling was accomplished with
a Grabball 600 mechanical scaler. The scaler, actu-
ally a modified hydraulic backhoe, was equipped
with a scaling tooth in place of the bucket. The
tooth was used to take or pry loose material from
the face and ribs to make an area safe for subsequent
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blasting was shot on November 26, 1975. In all, 38 full
rounds were shot in the campaign, advancing headings and
crosscuts a total of 692 feet. Other statistics are as
follows:

o Total mined	101,490 tons
o Advance per round	18.2 feet

- o Production per round 2,670 Tons
- o Explosives factor* 0.85 Pounds/Ton
- o Bit life** 327 Feet/Bit

* Explosives factor adversely affected by particle size limitation set by plant's primary crusher.

** Bit life adversely affected by use of 24 sub-standard bits.

- o Production per round 2,570 tons
- o Explosives factor 0.82 pounds/Ton
- o Bit life 327 Feet/Bit

* Explosives factor adversely affected by particle size limitation set by plant's primary crusher.

** Bit life adversely affected by use of 24 sub-standard bits.

**4. INDUSTRIAL
ENGINEERING**

5. APPENDIX

4. INDUSTRIAL ENGINEERING

4.1 Man/Machine Work Studies

Productivity and cycle times for the various mining functions in a commercial sized operation were developed from data obtained from time studies of the Anvil Points mine operation. Each function was studied with the objective of developing data that met 95% statistical confidence limits. This data, which was based on the prototype equipment, was used in the development of productivity and cycle times for the equipment envisioned for a commercial sized operation. Standard industrial and mining engineering techniques were used in the analyses of the data.

The specific functions studies were drilling, charging, and blasting, loading, hauling, roof bolting, scaling, and ventilation.

4.2 Equipment Testing

4.2.1 Drilling: During the mining program at Anvil Points, several drill manufacturers were offered an opportunity to test their equipment in oil shale. It was desired to investigate fully all potential oil shale drill candidates. Garner-Denver, Ingersoll-Rand, and Joy responded. Straight rotary, rotary-

4. INDUSTRIAL ENGINEERING

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4.2. Equipment Testing

4.2.1 Drilling: During the mining program at Anvil Point, several drill manufacturers were offered an opportunity to test their equipment in oil shale. It was desired to investigate fully all potential oil shale drill candidates. Garner-Denver, Ingersoll-Rand, and Joy responded. Straight rotary, rotary-

percussion and percussion drill actions were subsequently investigated.

Reports of the drilling tests have been published. Results can be generally summarized as follows:

- o Rotary drill action is preferred for drilling the richer oil shales. However, in lean shale (-20 gpt) rotary drill penetration rates are unacceptably low. Other types of drilling should be considered if lean shale is to be mined.
- o Rotary-percussion drill action is a potential means of drilling oil shale providing bits of proper design can be obtained. In contrast to straight rotary drill action, this type of drilling resulted in faster bit penetration in the lean shale than in the richer kerogen bearing rock.
- o Percussion drilling, using large compressed air operated drills, appears to be competitive with other types of drilling actions. In addition, a longer bit life appears likely with this type of equipment. The primary disadvantage in use of percussion

percussion and percussion drill actions were subse-
quently investigated.

Reports of the drilling tests have been published.
Results can be generally summarized as follows:

o Rotary drill action is preferred for drill-
ing the richer oil shales. However, in lean
shale (1-10 gpt) rotary drill penetration
rates are unacceptably low. Other types of
drilling should be considered if lean shale
is to be mined.

o Rotary-percussion drill action is a poten-
tial means of drilling oil shale providing
bits of proper design can be obtained. In
contrast to straight rotary drill action,
this type of drilling resulted in faster
bit penetration in the lean shale than in
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o Percussion drilling, using large compressed
air operated drills, appears to be competi-
tive with other types of drilling actions.
In addition, a longer bit life appears
likely with this type of equipment. The
primary disadvantage in use of percussion

drills is the requirement of large volumes of compressed air.

4.2.2 Scaling: A Drott-Cruz-Air, Model 40YR, rubber tired, hydraulic backhoe, equipped with a single ripper tooth in place of the conventional bucket, was tested for its ability to serve as a mechanical scaler. The machine performed well and will warrant consideration when equipping a commercial oil shale mine.

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of compressed air.

4.1.2 Scalings: A Brock-Cross-Air, Model 40YR, rubber
tired, hydraulic machine, equipped with a single
ripper tooth in place of the conventional bucket,
was tested for its ability to serve as a mechanical
scaler. The machine performed well and will warrant
consideration when equipping a commercial oil shale
mine.

5. APPENDIX

The following reports prepared by The Cleveland-Cliffs Iron Company for the Paraho Oil Shale Demonstration are included herein:

- 5.1 Gardner-Denver Drill and Bit Test
- 5.2 Gardner-Denver All Hydraulic Rotary Percussion Drill Test
- 5.3 Ingersoll-Rand Rotary-Percussion Drill Tests
- 5.4 Joy Drill and Bit Test
- 5.5 Man/Machine Work Studies
 - 5.5.1 Face Drilling
 - 5.5.2 Charging and Blasting
 - 5.5.3 Scaling
 - 5.5.4 Roof Bolting
 - 5.5.5 Ventilation
 - 5.5.6 Truck Loading and Hauling

2. APPENDIX

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- 2.1 Gardner-Denver Drill and Bit Test
- 2.2 Gardner-Denver All Hydraulic Rotary Percussion Drill Test
- 2.3 Ingersoll-Rand Rotary-Percussion Drill Tests
- 2.4 Joy Drill and Bit Test
- 2.5 Machine Work Studies
 - 2.5.1 Face Drilling
 - 2.5.2 Chipping and Blasting
 - 2.5.3 Scaling
 - 2.5.4 Rock Bolting
 - 2.5.5 Ventilation
 - 2.5.6 Truck Loading and Hauling

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FAIRMER-DEMER DRILL & BIT TEST REPORT
PAVING DEMONSTRATION PROJECT
FEBRUARY 1978

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PHASE ONE

INTRODUCTION

The first phase test involved the testing of various bit types in order to determine which bit type performed best in the drilling of oil shale. Also a down-the-hole hammer was tested with the above bits. The tests were accomplished in three phases, one with a Gardner-Denver bench rig equipped with a 63 RPM drill motor using rotary and rotary percussion (a Mission Megadrill down the hole hammer) type drilling; two, using the bench rig equipped with a 145 RPM drill motor with straight rotary drilling; and three, using the mine's Gardner-Denver jumbo equipped with a J.E.D.-1 drill with hard (110 RPM) and soft (170 RPM) rotary speeds. Straight rotary drilling was used in this phase of the test. Results of the three phases are recorded in the following sections.

Gardner-Denver Company sustained the majority of the cost of drilling equipment and supplies used in these tests.

Bits tested in this phase included Ram Claw bits made by Kennock Bit Company, four wing drag bits made by Kay Bit Company and Gault Tool Company and some special made bits from Kay Bit Company. One tri-cone roller bit, made by Burrel, was also tested. A hole-by-hole breakdown on this section is included on pages 3 to 10. Figure 1, page 42, is a sketch of a four wing drag bit.

INTRODUCTION

These Gardner-Denver drill and bit tests were conducted at the Paraho Demonstration Project's Arvill Point mine near Rifle, Colorado. The tests were accomplished in three phases, one with a Gardner-Denver bench rig equipped with a 63 RPM drill motor using rotary and rotary percussion (a Mission Megadrill down the hole hammer) type drilling; two, using the bench rig equipped with a 1A5 RPM drill motor with straight rotary drilling; and three, using the mine's Gardner-Denver jumbo equipped with a J.E.D.-1 drill with hard (110 RPM) and soft (170 RPM) rotary speeds. Straight rotary drilling was used in this phase of the test. Results of the three phases are recorded in the following sections.

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PHASE ONE RESULTS

PHASE ONE

The first phase test involved the testing of various bit types in order to determine which bit type performed best in the drilling of oil shale. Also, a down-the-hole hammer was tested with the above bits.

The down-the-hole hammer was a T.R.W. Mission Megadrill which produced 1,200 blows per minute at approximately 100 foot pounds per blow.

Both horizontal and vertical holes were drilled during this phase. Horizontal holes were drilled within three to four feet on each side of the Mahogany marker while the vertical holes were collared in the floor 20 feet below the Mahogany marker. The vertical holes were drilled in medium and high grade shale. The horizontal holes were drilled in low grade shale.

Bits tested in this phase included Ken Claw bits made by Kenrock Bit Company, four wing drag bits made by Kay Bit Company and Gault Tool Company and some special made bits from Kay Bit Company. One tri-cone roller bit, made by Barrel, was also tested. A hole-by-hole breakdown on this section is included on pages 3 to 10. Figure 1, page 42, is a sketch of a four wing drag bit.

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Bits tested in this phase included Ken Claw bits made by Harnock Bit Company, four wing drag bits made by Kay Bit Company and Gault Tool Company and some special made bits from Kay Bit Company. One tri-cone roller bit, made by Burrell, was also tested. A hole-by-hole breakdown on this section is included on pages 3 to 10. Figure 1, page 42, is a sketch of a four wing drag bit.

PHASE ONE RESULTS

Gardner-Denver Bench Rig with 63 RPM drill motor - rotary and rotary percussion drilling. All pressures are hydraulic gauge pressures in pounds per square inch. The booster is hydraulic fluid flow in gallons per minute.

Ken Claw Bits (Point Contact Bits):

1. Bit - 4-3/4" four-toothed ripper with five button pilot starter
Vertical hole (straight rotary)
Collar -
Drill - 8 feet in 7.00 minutes - 1.14 feet/minute
Pressures (psi):
 Rotation - 900
 Down - 700
Booster - 36 gallons/minute
2. Bit - 4-3/4" four-toothed ripper with five button pilot starter
Vertical hole (straight rotary)
Collar -
Drill - 20 feet in 13.5 minutes - 1.48 feet/minute
Pressures (psi):
 Rotation - 1,000
 Down - 1,000
Booster - 38 gallons/minute
3. Bit - 4-3/4" four-toothed ripper with five button pilot starter
Vertical hole (straight rotary)
Collar -
Drill - 9 feet in 5.0 minutes - 1.80 feet/minute
Pressures (psi):
 Rotation - 1,000
 Down - 1,500 (bit bound)
Booster - 38 gallons/minute

PHASE ONE RESULTS

Gardner-Denver Ranch Rig with 63 RPM drill motor - rotary and rotary percussion drilling. All pressures are hydraulic gauge pressures in pounds per square inch. The booster is hydraulic fluid flow in gallons per minute.

New Glen Site (Point Contact Site):

1. Bit - 4-3/4" four-coated ripper with five button pilot starter

Vertical hole (straight rotary)

Collar -

Drill - 8 feet in 7.00 minutes - 1.14 feet/minute

Pressures (psi):

Rotation - 900

Down - 700

Booster - 36 gallons/minute

2. Bit - 4-3/4" four-coated ripper with five button pilot starter

Vertical hole (straight rotary)

Collar -

Drill - 20 feet in 13.5 minutes - 1.48 feet/minute

Pressures (psi):

Rotation - 1,000

Down - 1,000

Booster - 38 gallons/minute

3. Bit - 4-3/4" four-coated ripper with five button pilot starter

Vertical hole (straight rotary)

Collar -

Drill - 9 feet in 5.0 minutes - 1.80 feet/minute

Pressures (psi):

Rotation - 1,000

Down - 1,300 (bit down)

Booster - 36 gallons/minute

Ken Claw Bits (Point Contact Bits) (Continued):

4. Bit - 4-3/4" four-toothed ripper with five button pilot starter

Horizontal hole (straight rotary)

Collar - 1.00 minutes

Drill - 20 feet in 20.87 minutes - 0.96 feet/minute

Pressures (psi):

Rotation - 1,000

Down - 1,300

5. Bit - 4-3/4" five-toothed ripper "Mini-Mite"

Vertical hole (straight rotary)

Collar -

Drill - 12 feet in 12.14 minutes - 0.99 feet/minute

Pressures (psi):

Rotation - 800

Down - 1,000

Booster - 36 gallons/minute

6. Bit - 4-3/4" five-toothed ripper "Mini-Mite"

Horizontal hole (straight rotary) 10 feet below Mahogany marker

Collar -

Drill - 8 feet in 11.0 minutes - .72 feet/minute

Pressures (psi):

Rotation - 750

Down - 1,000

Booster - 36 gallons/minute

7. Bit - 4-3/4" five-toothed ripper "Mini-Mite"

Vertical hole (straight rotary)

Collar - .62

Drill - 20.7 feet in 19.4 minutes - 1.06 feet/minute

Pressures (psi):

Rotation - 1,000

Down - 1,200

Booster - 38 gallons/minute

San Jose (Continued):

4. Sit - 4-3/4" five-toothed ripper with five button pilot scarer

Horizontal hole (straight rotary)

Collar -

Drill - 20 feet in 20.87 minutes - 0.96 feet/minute

Pressure (psi):

Rotation - 1,000

Down - 1,300

5. Sit - 4-3/4" five-toothed ripper "Mini-Mite"

Vertical hole (straight rotary)

Collar -

Drill - 12 feet in 12.14 minutes - 0.99 feet/minute

Pressure (psi):

Rotation - 800

Down - 1,000

Booster - 36 gallons/minute

6. Sit - 4-3/4" five-toothed ripper "Mini-Mite"

Horizontal hole (straight rotary) 10 feet below Mahogany marker

Collar -

Drill - 8 feet in 11.6 minutes - 0.72 feet/minute

Pressure (psi):

Rotation - 750

Down - 1,000

Booster - 36 gallons/minute

7. Sit - 4-3/4" five-toothed ripper "Mini-Mite"

Vertical hole (straight rotary)

Collar - .82

Drill - 20.7 feet in 19.4 minutes - 1.06 feet/minute

Pressure (psi):

Rotation - 1,000

Down - 1,300

Booster - 36 gallons/minute

Kay & Gault Bits (Continued):

11. Ken Claw Bits (Point Contact Bits) (Continued):
8. Bit - 4-3/4" four-toothed ripper
Vertical hole with rotary percussion hammer
Collar - 1.00 minute
Drill - 23.34 feet in 6.91 minutes - 3.37 feet/minute
Pressures (psi):
Rotation - 1,300
Down - 1,000

12. Booster - 38 gallons/minute

Kay & Gault Bits:

9. Bit - 4-1/4" Kay rotary-percussion bit
Vertical hole with rotary percussion hammer
Collar -
Drill - 23.34 feet in 15.65 minutes - 1.49 feet/minute
Pressures (psi):
Rotation - 700
Down - 320
Booster - 36 gallons/minute
10. Bit - 4-1/4" Kay resharpended drag bit
Vertical hole (straight rotary)
Collar -
Drill - 20.7 feet in 9.41 minutes - 2.20 feet/minute
Pressures (psi):
Rotation - 950
Down - 1,600
Booster - 38 gallons/minute

New Claw Bits (Joint Contact Bits) (Continued):

8. Bit - 4-3/4" form-coated ripper

Vertical hole with rotary percussion hammer

Collar - 1.00 minute

Drill - 23.36 feet in 6.91 minutes - 3.37 feet/minute

Pressure (psi):

Rotation - 1,300

Down - 1,000

Rooster - 38 gallons/minute

New & Grade Bits:

9. Bit - 4-1/4" Key rotary-percussion bit

Vertical hole with rotary percussion hammer

Collar -

Drill - 23.34 feet in 12.62 minutes - 1.85 feet/minute

Pressure (psi):

Rotation - 700

Down - 320

Rooster - 36 gallons/minute

10. Bit - 4-1/4" Key resharpened drag bit

Vertical hole (straight rotary)

Collar -

Drill - 20.7 feet in 9.41 minutes - 2.20 feet/minute

Pressure (psi):

Rotation - 950

Down - 1,600

Rooster - 38 gallons/minute

Kay & Gault Bits (Continued):

11. Bit - 4-1/4" Kay resharpened drag bit (same as #10)

Vertical hole with rotary percussion hammer

Collar -

Drill - 23.34 feet in 6.78 minutes - 3.44 feet/minute

Pressures (psi):

Rotation - 1,000

Down - 1,400

Booster - 38 gallons/minute

12. Bit - 4-1/4" Gault resharpened drag bit

Vertical hole with rotary percussion hammer

Collar -

Drill - 23.34 feet in 5.01 minutes - 4.66 feet/minute

Pressures (psi):

Rotation - 1,200

Down - 1,400

Booster - 38 gallons/minute

13. Bit - 4-1/4" Kay special drag bit

Vertical hole (straight rotary)

Collar -

Drill - 20.7 feet in 8.5 minutes - 2.43 feet/minute

Pressures (psi):

Rotation - 900

Down - 1,400

Booster - 36 gallons/minute

14. Bit - 4-1/4" Kay special drag bit

Vertical hole with rotary percussion hammer

Collar - .24

Drill - 23.34 feet in 5.43 minutes - 4.29 feet/minute.
(Tore all four carbides from seatings)

Pressures (psi):

Rotation - 1,200-1,300

Down - 1,400

Booster - 38 gallons/minute

Key & Gault Blks (Continued):

11. Blc - 4-1/4" Key resharpened drag bit (same as #10)

Vertical hole with rotary percussion hammer

Collar -

Drill - 23.34 feet in 6.78 minutes - 3.44 feet/minute

Pressure (psi):

Rotation - 1,000

Down - 1,400

Booster - 38 gallons/minute

12. Blc - 4-1/4" Gault resharpened drag bit

Vertical hole with rotary percussion hammer

Collar -

Drill - 23.34 feet in 5.01 minutes - 4.66 feet/minute

Pressure (psi):

Rotation - 1,200

Down - 1,400

Booster - 38 gallons/minute

13. Blc - 4-1/4" Key special drag bit

Vertical hole (straight rotary)

Collar -

Drill - 20.7 feet in 8.5 minutes - 2.43 feet/minute

Pressure (psi):

Rotation - 900

Down - 1,400

Booster - 38 gallons/minute

14. Blc - 4-1/4" Key special drag bit

Vertical hole with rotary percussion hammer

Collar - .34

Drill - 23.34 feet in 5.43 minutes - 4.30 feet/minute

(Turn all four cutters from settings)

Pressure (psi):

Rotation - 1,200-1,300

Down - 1,400

Booster - 38 gallons/minute

Kay & Gault Bits (Continued):

15. Bit - 4-1/4" Gault resharpened bit with two broken carbides

Vertical hole with rotary percussion hammer

(This bit attained 4.66 feet/minute on a previously drilled hole)

Collar - .46

Drill - 23.34 feet in 7.69 minutes - 3.03 feet/minute

Pressures (psi):

Rotation - 1,000

Down - 1,400

Booster - 38 gallons/minute

16. Bit - 4-1/4" Gault resharpened bit (same bit as #15)

Vertical hole with rotary percussion hammer

Collar -

Drill - 23.34 feet in 10.04 minutes - 2.32 feet/minute

(Tore the remaining two carbide inserts from their seatings)

Pressures (psi):

Rotation - No Recordings

Down - No Recordings

Booster - 36 gallons/minute

17. Bit - 4-1/4" Barrel Tri-Cone Roller Bit

Vertical hole with rotary percussion hammer

Collar -

Drill - 23.34 feet in 17.28 minutes - 1.35 feet/minute

Pressures (psi):

Rotation - 900

Down - 1,200

Booster - 38 gallons/minute

18. Bit - 4-1/4" Tri-Cone Roller Bit (same bit as #17)

Vertical hole (straight rotary)

Collar -

Drill - 1.5 feet in 2 minutes - .75 feet/minute

Pressures (psi):

Rotation - 800

Down - 1,400

Booster - 36 gallons/minute

Way & Gault Bites (Continued):

15. Bit - 4-1/4" Gault resharpened bit with two broken carbides

Vertical hole with rotary percussion hammer
(This bit attained 4.66 feet/minute on a previously drilled hole)

Collar - 4.66

Drill - 23.34 feet in 7.69 minutes - 3.03 feet/minute

Pressures (psi):
Rotation - 1,000
Down - 1,400

Booster - 38 gallons/minute

16. Bit - 4-1/4" Gault resharpened bit (same bit as #15)

Vertical hole with rotary percussion hammer

Collar -

Drill - 23.34 feet in 10.04 minutes - 2.32 feet/minute
(Turn the remaining two carbide inserts from their settings)

Pressures (psi):
Rotation - No Recordings
Down - No Recordings

Booster - 38 gallons/minute

17. Bit - 4-1/4" Barrel Tri-Gone Roller Bit

Vertical hole with rotary percussion hammer

Collar -

Drill - 23.34 feet in 17.28 minutes - 1.35 feet/minute

Pressures (psi):
Rotation - 900
Down - 1,200

Booster - 38 gallons/minute

18. Bit - 4-1/4" Tri-Gone Roller Bit (same bit as #17)

Vertical hole (straight rotary)

Collar -

Drill - 1.5 feet in 2 minutes - .75 feet/minute

Pressures (psi):
Rotation - 800
Down - 1,400

Booster - 38 gallons/minute

Kay & Gault Bits (Continued):

19. Bit - 4-1/4" Tri-Cone roller bit (same bit as #17-#18)

Vertical hole with rotary percussion hammer

Collar -

Drill - 22 feet in 17.15 minutes - 1.28 feet/minute
(bit destroyed - one roller tore out)

Pressures (psi):

Rotation - 900

Down - 1,400

Booster - 38 gallons/minute

The following horizontal holes were drilled in hard zones above and below the Mahogany marker.

20. Bit - 4-1/4" Gault resharpened bit

3.5 feet above Mahogany marker with rotary percussion hammer

Collar - .26

Drill - 23.34 feet in 9.34 minutes - 2.49 feet/minute
(tore three carbide inserts from seatings and chipped the fourth)

Pressures (psi):

Rotation - 900

Down - 1,000

Booster - 38 gallons/minute

21. Bit - 4-1/4" Kay Button "P" bit

3.0 feet above Mahogany Marker with rotary percussion hammer

Collar - .26

Drill - 23.34 feet in 18.06 minutes - 1.29 feet/minute

Pressures (psi):

Rotation - 900

Down - 500

Booster - 41 gallons/minute

Key & Gault Bits (Continued):

19. Bit - 4-1/4" Tri-Core roller bit (same bit as #17-#18)

Vertical hole with rotary percussion hammer

Collar -

Drill - 22 feet in 17.15 minutes - 1.28 feet/minute
(bit destroyed - one roller core out)

Pressure (psi):
Rotation - 900
Down - 1,400

Booster - 38 gallons/minute

The following horizontal holes were drilled in hard zones above and below the Mahogany marker.

20. Bit - 4-1/4" Gault resharpened bit

3.5 feet above Mahogany marker with rotary percussion hammer

Collar - .26

Drill - 23.34 feet in 9.34 minutes - 2.49 feet/minute
(core three carbide inserts from settings and chipped the fourth)

Pressure (psi):
Rotation - 800
Down - 1,000

Booster - 38 gallons/minute

21. Bit - 4-1/4" Key Button "T" bit

3.0 feet above Mahogany marker with rotary percussion hammer

Collar - .26

Drill - 23.34 feet in 18.06 minutes - 1.29 feet/minute

Pressure (psi):
Rotation - 900
Down - 900

Booster - 41 gallons/minute

The following horizontal holes were drilled in hard zones above and below the Mahogany marker.

Kay & Gault Bits (Continued):

22. Bit - 4-1/4" Kay rotary percussion bit

2.5 feet above Mahogany marker with rotary percussion hammer

Collar - .88

Drill - 23.34 feet in 21.24 minutes - 1.09 feet/minute

Pressures (psi):

Rotation - 850

Down - 500

Booster - 41 gallons/minute

23. Bit - 4-1/4" Kay resharpened drag bit

Drilled in Mahogany marker with rotary percussion hammer

Collar -

Drill - 5 feet in 3.86 minutes - 1.29 feet/minute
(bit completely destroyed)

Pressures (psi):

Rotation - 850

Down - 1,000

Booster - 41 gallons/minute

24. Bit - 4-1/4" Kay Button "P" bit

.5 feet above Mahogany marker with rotary percussion hammer

Collar -

Drill - 23.34 feet in 18.35 minutes - 1.27 feet/minute

Pressures (psi):

Rotation - 750

Down - 500

Booster - 36 gallons/minute

The following horizontal holes were drilled in hard zones above and below the Helgany member:

Key & Gauge Holes (Continued):

22. Bit - 4-1/4" Key rotary percussion bit

1.2 feet above Helgany member with rotary percussion hammer

Collar - .88

Drill - 23.34 feet in 21.24 minutes - 1.09 feet/minute

Pressures (psi):
Rotation - 850
Down - 500

Booster - 41 gallons/minute

23. Bit - 4-1/4" Key rotary percussion drag bit

Drilled in Helgany member with rotary percussion hammer

Collar -

Drill - 5 feet in 3.86 minutes - 1.29 feet/minute
(bit completely destroyed)

Pressures (psi):
Rotation - 850
Down - 1,000

Booster - 41 gallons/minute

24. Bit - 4-1/4" Key Button "P" bit

1.2 feet above Helgany member with rotary percussion hammer

Collar -

Drill - 23.34 feet in 18.35 minutes - 1.27 feet/minute

Pressures (psi):
Rotation - 750
Down - 100

Booster - 35 gallons/minute

SUMMARY:

Kay & Gault Bits (Continued):

25. Bit - 4-1/4" Kay rotary percussion bit

2.2 feet above Mahogany marker with rotary percussion hammer

Collar - .48

Drill - 23.34 feet in 18.03 minutes - 1.30 feet/minute

Pressures (psi):

Rotation - 850

Down - 500

Booster - 41 gallons/minute

Key & Gentle Blue (Continued):

25. Bit - 4-1/4" Key rotary percussion bit

2.2 feet above Neogay marker with rotary percussion hammer

Collar - .48

Drill - 23.34 feet in 18.03 minutes - 1.30 feet/minute

Pressure (psi):

Rotation - 850

Down - 500

Rooster - 41 gallons/minute

SUMMARY:

Results from this test indicated that four wing drag bits performed best with straight rotary drilling. When used with rotary percussion drilling they attained good penetration rates but did not hold up well. Most drag bits were destroyed when the carbide inserts were torn from their seatings, usually during rotary percussion drilling.

The Ken Claw (point contact) bits, made by Kenrock Bit Company did not perform well with either rotary or rotary percussion drilling. The special bits, one a rotary percussion type bit and the other a button type bit, made by Kay Bit Company, did not perform as well as expected. Cutting and clearance angles on the rotary percussion bit were not applicable to the drilling of oil shale. This was the first rotary percussion bit tried. The cutting and clearance angles were not applicable to the drilling of oil shale as there was no bit sharpening equipment for experimentation with different angles.

The tri-cone roller bit, made by Barrel, was destroyed when one roller was torn from its mounting. This was during rotary percussion drilling. Penetration rates with this bit were less than 1.5 feet per minute.

In conclusion, it was substantiated that drag bits work best in rotary drilling of oil shale. With regard to rotary percussion drilling of oil shale, it was substantiated that drag bits would not hold up under the percussion impact. In testing for a bit that will satisfactorily drill oil shale with rotary percussion drilling, it is suggested that percussion and rotary percussion type bits be tested. Also, these bits should be sharpened to various angles in an attempt to find optimum angles for drilling oil shale.

Results from this test indicated that four wing drag bits performed best with straight rotary drilling. When used with rotary percussion drilling they attained good penetration rates but did not hold up well. Most drag bits were destroyed when the carbide inserts were torn from their seatings, usually during rotary percussion drilling.

The New Claw (point contact) bits, made by Kennock Bit Company did not perform well with either rotary or rotary percussion drilling. The special bits, one a rotary percussion type bit and the other a button type bit, made by Ray Bit Company, did not perform as well as expected. Cutting and clearance angles on the rotary percussion bit were not applicable to the drilling of oil shale. This was the first rotary percussion bit tried. The cutting and clearance angles were not applicable to the drilling of oil shale as there was no bit sharpening equipment for experimentation with different angles.

The cut-cone roller bit, made by Baxtel, was destroyed when one roller was torn from its mounting. This was during rotary percussion drilling. Penetration rates with this bit were less than 1.5 feet per minute.

In conclusion, it was substantiated that drag bits work best in rotary drilling of oil shale. With regard to rotary percussion drilling of oil shale, it was substantiated that drag bits would not hold up under the percussion impact. In testing for a bit that will satisfactorily drill oil shale with rotary percussion drilling, it is suggested that percussion and rotary percussion type bits be tested. Also, these bits should be sharpened to various angles in an attempt to find optimum angles for drilling oil shale.

PHASE TWO

The second phase of this test deals with various four wing drag bits with different clearance and rake angles in an attempt to determine optimum angles with respect to penetration rates. Also, an attempt was made to substantiate that precision bit sharpening is necessary for attaining good penetration rates and the longest possible bit life. The bits in this section were recorded by their carbide hardness and by an angle in degrees. This angle is the clearance angle measured from vertical minus the rake angle (example 1-8 -22°). Figure 1 on page 42 shows a typical four wing drag bit. The bits used in this phase of the test were all Kay and Gault four wing drag type bits furnished, at no cost, by Gardner-Denver Company.

A 145 rpm drill motor was used on a Gardner-Denver bench rig for this test. A hole-by-hole breakdown on this section is included on pages 13 to 26. Most bits were recorded by the degree of the angles on that particular bit. The first 15 holes were drilled with the booster compressor connected, the remaining 35 holes were drilled with the booster compressor disconnected. The booster was disconnected to better distribute the hydraulic power to the remaining active systems. Cleaning of the hole became a problem while the booster compressor was disconnected.

All holes drilled in this phase of the test were vertical. They were collared some 20 feet below the Mahogany marker and were drilled through both medium and high grade shale.

PHASE TWO

The second phase of this test deals with various four wing drag

bites with different clearance and rake angles in an attempt to determine optimum angles with respect to penetration rates. Also, an attempt was made to substantiate that penetration bit sharpening is necessary for attaining good penetration rates and the longest possible bit life. The bite in this section was recorded by their carbide hardness and by an angle in degrees. This angle is the clearance angle measured from vertical minus the rake angle (example 1-8-22°). Figure 1 on page 42 shows a typical four wing drag bite. The bite used in this phase of the test were all Kay and Gaul four wing drag type bits furnished, at no cost, by Gardner-Denver Company.

A 1/2 hp drill motor was used on a Gardner-Denver bench rig for this test. A hole-by-hole breakdown on this section is included on pages 13 to 16. Most bits were recorded by the degree of the angles on that particular bite. The first 15 holes were drilled with the booster compressor connected, the remaining 35 holes were drilled with the booster compressor disconnected. The booster was disconnected to better distribute the hydraulic power to the remaining active systems. Cleaning of the hole became a problem while the booster compressor was disconnected. All holes drilled in this phase of the test were vertical.

They were collared some 20 feet below the Mercury marker and were drilled through both medium and high grade shale.

All holes drilled to a depth of 15 feet. The pressures are hydraulic gauge pressures in pounds per square inch. The booster is hydraulic fluid flow in gallons

PHASE TWO RESULTS

1. #4 Standard Carbide:

Gardner-Denver Bench Rig with 145 RPM drill motor - rotary drilling with and without a booster compressor (vertical holes)

Two (2) holes drilled with the mine jumbo - horizontal holes:

#4 Carbide: Standard Carbide:

10 feet above the Mahogany marker (black seam)

Collar the hole - .32

Drill the hole - 25 feet in 3.82 minutes - 6.8 feet/minute

Retract drill - .88

Pressures (psi):

Drill - 1,400

Down (Feed) - 900

#8 Carbide:

Top hole (hard drilling) 15 feet above Mahogany marker

Collar the hole - .35

Drill the hole - 26 feet in 5.83 minutes - 4.4 feet/minute

Retract drill - 1.11

Pressures (psi):

Drill - 1,450 (end of hole 1,100)

Feed - 1,000

* Varies due to hardness of rock being drilled.

PHASE TWO RESULTS

Gardner-Denver Bench Rig with 145 RPM drill motor - rotary drilling

with and without a booster compressor (vertical holes)

Two (2) holes drilled with the mine jumbo - horizontal holes:

48 Cartridges

10 feet above the Mahogany marker (black beam)

Collar the hole - .32

Drill the hole - 25 feet in 3.82 minutes - 6.6 feet/minute

Retract drill - .88

Pressures (psi):

Drill - 1,400

Down (Feed) - 900

48 Cartridges

Top hole (hard drilling) 15 feet above Mahogany marker

Collar the hole - .32

Drill the hole - 25 feet in 3.83 minutes - 6.4 feet/minute

Retract drill - 1.11

Pressures (psi):

Drill - 1,450 (end of hole 1,100)

Feed - 1,000

All holes drilled to a depth of 18 feet. The pressures are hydraulic gauge pressures in pounds per square inch. The booster is hydraulic fluid flow in gallons per minute.

1. #4 Standard Carbide:

Collar - .09

Drill - 3.68 minutes - 4.89 feet/minute

Pressures (psi):

Rotation - 1,450

Down - 1,200

Booster - 38 gallons/minute

2. #4 Standard Carbide:

Collar - .15

Drill - 4.02 minutes - 4.47 feet/minute

Pressures (psi):

Rotation - 1,250 - 1,500*

Down - 700

Booster - 41 gallons/minute

3. #8 Standard Carbide:

Collar - .18

Drill - 3.59 minutes - 5.01 feet/minute

Pressures (psi):

Rotation - 1,000 - 1,500*

Down - 700

Booster - 41 gallons/minute

4. #8 Standard Carbide:

Collar -

Drill - 3.62 minutes - 4.97 feet/minute

Pressures (psi):

Rotation - 1,000 - 1,500*

Down - 700

Booster - 41 gallons/minute

* Varies due to hardness of rock being drilled.

All holes drilled to a depth of 18 feet. The pressures are hydraulic gauge pressures in pounds per square inch. The booster is hydraulic fluid flow in gallons per minute.

1.	48 Standard Carbide:
	Collar - .09
	Drill - 3.68 minutes - 4.89 feet/minute
	Pressures (psi):
	Rotation - 1,450
	Down - 1,200
	Booster - 38 gallons/minute
2.	48 Standard Carbide:
	Collar - .15
	Drill - 4.02 minutes - 4.47 feet/minute
	Pressures (psi):
	Rotation - 1,250 - 1,500*
	Down - 700
	Booster - 41 gallons/minute
3.	48 Standard Carbide:
	Collar - .18
	Drill - 3.59 minutes - 5.01 feet/minute
	Pressures (psi):
	Rotation - 1,000 - 1,500*
	Down - 700
	Booster - 41 gallons/minute
4.	48 Standard Carbide:
	Collar -
	Drill - 3.62 minutes - 4.97 feet/minute
	Pressures (psi):
	Rotation - 1,000 - 1,500*
	Down - 700
	Booster - 41 gallons/minute

* Values due to hardness of rock being drilled.

5. #8 Standard Carbide:
Collar - .19
Drill - 3.98 minutes - 4.52 feet/minute
Pressures (psi):
Rotation - 1,000 - 1,500*
Down - 700
Booster - 41 gallons/minute
6. Gault Reground (relieved):
Collar -
Drill - 3.08 minutes - 5.84 feet/minute
Pressures (psi):
Rotation - 1,000 - 1,500*
Down - 700
Booster - 42 gallons/minute
7. Gault Reground (NOT relieved):
Collar - .10
Drill - 3.70 minutes - 4.86 feet/minute
Pressures (psi):
Rotation - 1,000 - 1,500*
Down - 700
Booster - 41 gallons/minute
8. 1-8 - 22°:
Collar - .20
Drill - 2.94 minutes - 6.12 feet/minute
Pressures (psi):
Rotation - 1,000 - 1,500*
Down - 700
Booster - 41 gallons/minute

* Varies due to the hardness of rock being drilled.

* Varies due to hardness of rock being drilled.

* Values due to hardness of rock being drilled.

8.

Drill - 2.96 minutes - 6.12 feet/minute
 Pressure (psi):
 Rotation - 1,000 - 1,500*
 Down - 700
 Booster - 41 gallons/minute

Collar - 20

I-B - 22°

Booster - 41 gallons/minute

Pressure (psi):
 Rotation - 1,000 - 1,500*
 Down - 700

Drill - 3.70 minutes - 4.86 feet/minute

Collar - 10

Gault Reground (NOT reloaded):

Booster - 42 gallons/minute

Pressure (psi):
 Rotation - 1,000 - 1,500*
 Down - 700

Drill - 3.08 minutes - 5.84 feet/minute

Collar -

Gault Reground (reloaded):

Booster - 41 gallons/minute

Pressure (psi):
 Rotation - 1,000 - 1,500*
 Down - 700

Drill - 3.98 minutes - 4.52 feet/minute

Collar - 19

5.

48 Standard Cartridges

9. 1-4 - 28°:
Collar - .35
Drill - 4.49 minutes - 4.00 feet/minute
Pressures (psi):
Rotation - 1,000 - 1,500*
Down - 700
Booster - 41 gallons/minute
10. 2-4 - 25°:
Collar - .08
Drill - 3.81 minutes - 4.72 feet/minute
Pressures (psi):
Rotation - 1,000 - 1,500*
Down - 700
Booster - 41 gallons/minute
11. 2-8 - 24°:
Collar - .09
Drill - 3.06 minutes - 5.88 feet/minute
Pressures (psi):
Rotation - 1,000 - 1,500*
Down - 700
Booster - 41 gallons/minute
12. 3-4 - 18°:
Collar -
Drill - 2.98 minutes - 6.04 feet/minute
Pressures (psi):
Rotation - 1,000 - 1,500*
Down - 700
Booster - 41 gallons/minute

* Varies due to the hardness of rock being drilled.

9. 1-4 - 28°
 Collar - .35
 Drill - 4.49 minutes - 4.00 feet/minute
 Pressure (psi):
 Rotation - 1,000 - 1,500*
 Down - 700
 Booster - 41 gallons/minute

10. 2-4 - 25°
 Collar - .09
 Drill - 3.81 minutes - 4.75 feet/minute
 Pressure (psi):
 Rotation - 1,000 - 1,500*
 Down - 700
 Booster - 41 gallons/minute

11. 2-8 - 24°
 Collar - .09
 Drill - 3.06 minutes - 5.88 feet/minute
 Pressure (psi):
 Rotation - 1,000 - 1,500*
 Down - 700
 Booster - 41 gallons/minute

12. 3-4 - 18°
 Collar -
 Drill - 2.98 minutes - 6.04 feet/minute
 Pressure (psi):
 Rotation - 1,000 - 1,500*
 Down - 700
 Booster - 41 gallons/minute

* Varies due to the hardness of rock being drilled.

13. 3-8 - 18°:
Collar - .19

Drill - 3.03 minutes - 5.94 feet/minute

Pressures (psi):

Rotation - 1,000 - 1,500*

Down - 700

Booster - 41 gallons/minute

14. Old Kay (resharpened):

Collar - .10

Drill - 6.54 minutes - 2.18 feet/minute

Pressures (psi):

Rotation - 1,000 - 1,500

Down - 700

Booster - 41 gallons/minute

15. Gault (relieved) Reground:

Collar - .10

Drill - 3.30 minutes - 5.45 feet/minute

Pressures (psi):

Rotation - 1,000 - 1,500*

Down - 700

Booster - 41 gallons/minute

* Varies due to the hardness of rock being drilled.

13.	3-8 - 18°	Collar - .19	Drill - 3.03 minutes - 2.04 feet/minute	Pressure (psi): Rotation - 1,000 - 1,500* Down - 700	Booster - 41 gallons/minute
14.		Collar - .10	Drill - 6.54 minutes - 2.18 feet/minute	Pressure (psi): Rotation - 1,000 - 1,500 Down - 700	Booster - 41 gallons/minute
15.		Collar - .10	Drill - 3.30 minutes - 2.45 feet/minute	Pressure (psi): Rotation - 1,000 - 1,500* Down - 700	Booster - 41 gallons/minute

* Varies due to the hardness of rock being drilled.

All holes vertical - rotation (145 RPM). Booster compressor disconnected.
The compressor pressure is the hydraulic system pressure in pounds per square inch.

1. 1-8 - 22°:
Collar -
Drill - 2.85 minutes - 6.31 feet/minute
Pressures (psi):
Rotation - 1,250 - 1,500* (drilled dry)
Down - 800
Compressor - 3,800
2. 1-8 - 22°:
Collar - .08
Drill - 3.05 minutes - 5.90 feet/minute
Pressures (psi):
Rotation - 1,000 to 1,500* (drilled wet)
Down - 800
Compressor - 4,200
3. 1-8 - 22°:
Collar - .10
Drill - 3.80 minutes - 4.73 feet/minute
Pressures (psi):
Rotation - 1,200 - 1,700*
Down - 900 (bit dulling and binding)
Compressor - 4,000
4. 1-8 - 22°:
Collar - .11
Drill - 3.87 minutes - 4.65 feet/minute
Pressures (psi):
Rotation - 1,300 - 1,700*
Down - 1,000
Compressor - 4,200

* Varies due to hardness of rock being drilled.

All holes vertical - rotation (145 RPM). Booster compressor disconnected.
The compressor pressure is the hydraulic system pressure in pounds per square inch.

1.	1-8 - 22°	Drill - 2.85 minutes - 6.31 feet/minute	Collar -	Pressure (psi): Rotation - 1,250 - 1,500* (drilled dry) Down - 800 Compressor - 3,800
2.	1-8 - 22°	Drill - 3.05 minutes - 5.90 feet/minute	Collar - .08	Pressure (psi): Rotation - 1,000 to 1,500* (drilled wet) Down - 800 Compressor - 4,200
3.	1-8 - 22°	Drill - 3.80 minutes - 4.73 feet/minute	Collar - .10	Pressure (psi): Rotation - 1,200 - 1,700* Down - 900 (bit drilling and bleeding) Compressor - 4,000
4.	1-8 - 22°	Drill - 3.87 minutes - 4.65 feet/minute	Collar - .11	Pressure (psi): Rotation - 1,300 - 1,700* Down - 1,000 Compressor - 4,200

* Values due to hardness of rock being drilled.

5. 2-8 - 24°:
Collar - .09
Drill - 4.12 minutes - 4.37 feet/minute
Pressures (psi):
Rotation - 1,100 - 1,600
Down - 800
Compressor - 4,000
6. 2-8 - 24°:
Collar - .10
Drill - 4.23 minutes - 4.25 feet/minute
Pressures (psi):
Rotation - 1,200 - 1,600
Down - 900 (bit binding)
Compressor - 4,200
7. 2-8 - 24°:
Collar - .09
Drill - 4.08 minutes - 4.41 feet/minute
Pressures (psi):
Rotation - 1,200 - 1,600* (bit binding)
Down - 1,000
Compressor - 4,200
8. 2-4 - 25°:
Collar - .10
Drill - 4.33 minutes - 4.15 feet/minute
Pressures (psi):
Rotation - 1,200 - 1,700*
Down - 800
Compressor - 4,000

* Varies due to the hardness of rock being drilled.

* Values due to the hardness of rock being drilled.

9. 2-4 - 25°:
Collar - .08
Drill - 4.10 minutes - 4.39 feet/minute

Pressures (psi):
Rotation - 1,200 - 1,800
Down - 900

(bit binding)

Compressor - 4,200

10. 2-4 - 25°:
Collar - .09
Drill - 4.00 minutes - 4.50 feet/minute

Pressures (psi):
Rotation - 1,200 - 1,700*
Down - 1,000

Compressor - 3,300

11. 3-4 - 18°:
Collar - .11
Drill - 3.30 minutes - 5.45 feet/minute

Pressures (psi):
Rotation - 1,200 - 1,600*
Down - 800

Compressor - 4,200

12. 3-4 - 18°:
Collar - .08
Drill - 3.30 minutes - 5.45 feet/minute

Pressures (psi):
Rotation - 1,100 - 1,600*
Down - 900

(bit binding)

Compressor - 3,800

* Varies due to the hardness of rock being drilled.

* Varies due to hardness of rock being drilled.

9. 3-4 - 25°
 Collar - .08
 Drill - 4.10 minutes - 4.35 feet/minute
 Pressures (psi):
 Rotation - 1,200 - 1,800
 Down - 900
 Compressor - 4,200

10. 3-4 - 25°
 Collar - .09
 Drill - 4.00 minutes - 4.50 feet/minute
 Pressures (psi):
 Rotation - 1,200 - 1,700*
 Down - 1,000
 Compressor - 3,300

11. 3-4 - 18°
 Collar - .11
 Drill - 3.30 minutes - 2.42 feet/minute
 Pressures (psi):
 Rotation - 1,200 - 1,600*
 Down - 800
 Compressor - 4,200

12. 3-4 - 18°
 Collar - .08
 Drill - 3.30 minutes - 2.42 feet/minute
 Pressures (psi):
 Rotation - 1,100 - 1,600*
 Down - 900
 Compressor - 3,800

* Varies due to the hardness of rock being drilled.

13. 3-4 - 18°: *11 Points Grind:*
Collar - .12
Drill - 3.55 minutes - 5.07 feet/minute
Pressures (psi):
Rotation - 1,300 - 1,800*
Down - 1,000 (bit binding)
Compressor - 3,800
14. 3-8 - 18°: *11 Points Grind:*
Collar - .10
Drill - 3.01 minutes - 5.98 feet/minute
Pressures (psi):
Rotation - 1,200 - 1,700*
Down - 800
Compressor - 4,100
15. 3-8 - 18°: *Gault Anvil Points Grind:*
Collar - .08
Drill - 3.24 minutes - 5.55 feet/minute
Pressures (psi):
Rotation - 1,300 - 1,800*
Down - 900
Compressor - 4,000
16. 3-8 - 18°: *Gault Anvil Points Grind:*
Collar - .09
Drill - 2.99 minutes - 6.02 feet/minute
Pressures (psi):
Rotation - 1,300 - 1,800*
Down - 1,000 (bit binding)
Compressor - 3,800

* Varies due to hardness of rock being drilled.

13. 3-4 - 18°
 Collar - .12
 Drill - 3.55 minutes - 5.07 feet/minute
 Pressures (psi):
 Rotation - 1,300 - 1,800*
 Down - 1,000
 (bit binding)
 Compressor - 3,800

14. 3-8 - 18°
 Collar - .10
 Drill - 3.01 minutes - 5.98 feet/minute
 Pressures (psi):
 Rotation - 1,200 - 1,700*
 Down - 800
 Compressor - 4,100

15. 3-8 - 18°
 Collar - .08
 Drill - 3.34 minutes - 5.25 feet/minute
 Pressures (psi):
 Rotation - 1,300 - 1,800*
 Down - 900
 Compressor - 4,000

16. 3-8 - 18°
 Collar - .09
 Drill - 3.29 minutes - 6.02 feet/minute
 Pressures (psi):
 Rotation - 1,300 - 1,800*
 Down - 1,000
 (bit binding)
 Compressor - 3,800

* Varies due to hardness of rock being drilled.

17. New 8 - Anvil Points Grind:
Collar -
Drill - 4.88 minutes - 3.68 feet/minute
Pressures (psi):
Rotation - 1,200 - 1,300*
Down - 700
Compressor - 3,300
18. New 8 - Anvil Points Grind:
Collar - .08
Drill - 5.91 minutes - 3.04 feet/minute
Pressures (psi):
Rotation - 1,200 - 1,600*
Down - 800
Compressor - 3,500
19. Resharpened Gault Anvil Points Grind:
Collar - .11
Drill - 3.80 minutes - 4.73 feet/minute
Pressures (psi):
Rotation - 1,000 - 1,500*
Down - 700
Compressor - 3,600
20. Resharpened Gault Anvil Points Grind:
Collar - .09
Drill - 3.62 minutes - 4.97 feet/minute
Pressures (psi):
Rotation - 1,000 - 1,500*
Down - 800
Compressor - 3,900

* Varies due to the hardness of rock being drilled.

21. Resharpened Gault Bit Anvil Points Grind:
Collar - .10
Drill - 3.35 minutes - 5.37 feet/minute
Pressures (psi):
Rotation - 1,200 - 1,600*
Down - 900
Compressor - 3,900
22. Resharpened Gault Bit Anvil Points Grind:
Collar - .11
Drill - 3.70 minutes - 4.86 feet/minute
Pressures (psi):
Rotation - 1,200 - 1,600
Down - 1,000
Compressor - 4,100
23. Resharpened Gault (cracked insert):
Collar -
Drill - 3.80 minutes - 4.74 feet/minute
Pressures (psi):
Rotation - 1,000 - 1,500*
Down - 700
Compressor - 4,200
24. 1-8 Standard:
Collar - .09
Drill - 4.36 minutes - 4.13 feet/minute
Pressures (psi):
Rotation - 1,100 - 1,700*
Down - 900
Compressor - 4,200

* Varies due to the hardness of rock being drilled.

21. Reassembled Gault Bit Anvil Points Grind:

Collar - .10

Drill - 3.35 minutes - 5.37 feet/minute

Pressure (psi):

Rotation - 1,200 - 1,500*

Down - 200

Compressor - 3,900

22. Reassembled Gault Bit Anvil Points Grind:

Collar - .11

Drill - 3.70 minutes - 4.86 feet/minute

Pressure (psi):

Rotation - 1,200 - 1,500

Down - 1,000

Compressor - 4,100

23. Reassembled Gault (cracked insert):

Collar -

Drill - 3.80 minutes - 4.74 feet/minute

Pressure (psi):

Rotation - 1,000 - 1,500*

Down - 700

Compressor - 4,200

24. 1-8 Standard: Gault Bit Anvil Points Grind:

Collar - .09

Drill - 4.36 minutes - 4.13 feet/minute

Pressure (psi):

Rotation - 1,100 - 1,700*

Down - 900

Compressor - 4,200

* Varies due to the hardness of rock being drilled.

25. 1-8 Standard:
Collar - .09
Drill - 3.75 minutes - 4.80 feet/minute
Pressures (psi):
Rotation - 1,250 - 1,750*
Down - 1,100
Compressor - 3,900
26. 1-8 Standard:
Collar -
Drill - 4.31 minutes - 4.17 feet/minute (bit binding)
Pressures (psi):
Rotation - 1,250 - 1,750*
Down - 1,300
Compressor - 3,500
27. 1-8 Standard:
Collar - .08
Drill - 4.18 minutes - 4.30 feet/minute (bit binding)
Pressures (psi):
Rotation - 1,200 - 1,600*
Down - 1,200
Compressor - 3,600
28. 1-8 Standard:
Collar -
Drill - 4.08 minutes - 4.41 feet/minute
Pressures (psi):
Rotation - 1,100 - 1,600*
Down - 900
Compressor - 3,700

* Varies due to the hardness of rock being drilled.

25.	1-8 Standard: Collar - .09 Drill - 3.75 minutes - 4.80 feet/minute Pressure (psi): Rotation - 1,250 - 1,750* Power - 1,100 Compressor - 3,900
26.	1-8 Standard: Collar - Drill - 4.31 minutes - 4.17 feet/minute (oil binding) Pressure (psi): Rotation - 1,250 - 1,750* Power - 1,300 Compressor - 3,500
27.	1-8 Standard: Collar - .08 Drill - 4.18 minutes - 4.30 feet/minute (oil binding) Pressure (psi): Rotation - 1,200 - 1,600* Power - 1,200 Compressor - 3,600
28.	1-8 Standard: Collar - Drill - 4.08 minutes - 4.41 feet/minute Pressure (psi): Rotation - 1,100 - 1,600* Power - 900 Compressor

* Values due to the hardness of rock being drilled.

29. 1-8 Standard:
Collar - .10
Drill - 4.11 minutes - 4.38 feet/minute
Pressures (psi):
Rotation - 1,100 - 1,600*
Down - 1,000
Compressor - 3,900
30. 1-4 Standard:
Collar - .09
Drill - 4.55 minutes - 3.95 feet/minute (bit binding)
Pressures (psi):
Rotation - 1,100 - 1,500*
Down - 900
Compressor - 4,100
31. 1-4 Standard:
Collar - .07
Drill - 4.59 minutes - 3.92 feet/minute
Pressures (psi):
Rotation - 1,100 - 1,600*
Down - 1,000
Compressor - 3,700
32. 1-4 Standard:
Collar - .11
Drill - 4.60 minutes - 3.91 feet/minute
Pressures (psi):
Rotation - 1,100 - 1,600*
Down - 800
Compressor - 3,700

* Varies due to the hardness of rock being drilled.

29.	1-8 Standard: Collar - .10 Drill - 4.11 minutes - 4.38 feet/minute Pressure (psi): Rotation - 1,100 - 1,600* Down - 1,000 Compressor - 3,900
30.	1-4 Standard: Collar - .09 Drill - 4.55 minutes - 3.95 feet/minute (bit standing) Pressure (psi): Rotation - 1,100 - 1,500* Down - 900 Compressor - 4,100
31.	1-4 Standard: Collar - .07 Drill - 4.59 minutes - 3.92 feet/minute Pressure (psi): Rotation - 1,100 - 1,600* Down - 1,000 Compressor - 3,700
32.	1-4 Standard: Collar - .11 Drill - 4.60 minutes - 3.91 feet/minute Pressure (psi): Rotation - 1,100 - 1,600* Down - 800 Compressor - 3,700

* Varies due to the hardness of rock being drilled.

33. 1-4 Standard:

Collar - .09

Drill - 5.63 minutes - 3.19 feet/minute

Pressures (psi):

Rotation - 1,000 - 1,500*

Down - 700

Compressor - 3,600

34. 1-4 - 28°:

Collar - .08

Drill - 4.25 minutes - 4.23 feet/minute

Pressures (psi):

Rotation - 1,000 - 1,500*

Down - 900

Compressor - 4,200

35. 1-4 - 28°:

Collar - .14

Drill - 8.35 minutes - 2.15 feet/minute

Pressures (psi):

Rotation - 1,300 - 1,750*

Down - 1,000

Compressor - 3,800

* Varies due to the hardness of the rock being drilled.

* Values due to the hardness of the rock being drilled.

SUMMARY:

The second phase of this test dealt with the testing of various drag bits with different clearance and rake angles. These bits were precision sharpened in an attempt to substantiate that precision bit sharpening is necessary for maintaining good penetration rates with the longest possible bit life.

Results from the first 14 holes drilled in this phase indicate that good penetration rates can be attained at a relatively low feed pressure (700 psi); see drill hole information sheets, pages 13 to 26 and Table I, page 28. Each bit was tested at various feed pressures in an attempt to determine an optimum feed pressure for attaining maximum penetration rates. Results are found on the drill hole information sheets, pages 13 to 26 and Table II, page 29. The optimum feed pressure (best penetration rate) varied for each bit. Testing indicated that the clearance angle of each bit governs the feed pressure needed to attain the best penetration rates. On page 42. Figure 1 is a drawing of a typical drag bit.

Variation of feed pressure with some bits did not make a significant difference in penetration rates. These bits had about the same penetration rates with 700 psi as with 1,000 psi. This pressure is hydraulic gauge pressure in pounds per square inch.

The second phase of this test dealt with the testing of various drag bits with different clearance and rake angles. These bits were precision sharpened in an attempt to substantiate that precision bit sharpening is necessary for maintaining good penetration rates with the largest possible bit life.

Results from the first 14 holes drilled in this phase indicate that good penetration rates can be attained at a relatively low feed pressure (700 psi); see drill hole information sheets, pages 13 to 26 and Table I, page 28. Each bit was tested at various feed pressures in an attempt to determine an optimum feed pressure for attaining maximum penetration rates. Results are found on the drill hole information sheets, pages 13 to 26 and Table II, page 29. The optimum feed pressure (best penetration rate) varied for each bit. Testing indicated that the clearance angle of each bit governs the feed pressure needed to attain the best penetration rates. On page 41, Figure 1 is a drawing of a typical drag bit.

Variation of feed pressure with same bits did not make a significant difference in penetration rates. These bits had about the same penetration rates with 700 psi as with 1,000 psi. This pressure is hydraulic gauge pressure in pounds per square inch.

TABLE I

PHASE TWO - COMPARISON OF FEED PRESSURE (psi) AND PENETRATION
RATES (feet/minute) WITH THE BOOSTER COMPRESSOR CONNECTED

<u>BIT</u>	<u>FEED PRESSURE*</u> <u>(Psi)</u>	<u>PENETRATION RATE</u> <u>(feet/minute)</u>
#4 Standard	700	4.47
#8 Standard	700	5.01
#8 Standard	700	4.97
#8 Standard	700	4.52
Gault Reground (Relieved)	700	5.84
Gault Reground (Not Relieved)	700	4.86
1-8 - 22°	700	6.12
1-4 - 28°	700	4.00
2-4 - 25°	700	4.72
2-8 - 25°	700	5.88
3-4 - 18°	700	6.04
3-8 - 18°	700	5.94
Kay Resharpened	700	2.18
Gault Resharpened (Relieved)	700	5.45

* First 14 holes were drilled at a constant feed pressure to determine which bit performed best at this pressure.

TABLE I

PHASE TWO - COMPARISON OF FEED PRESSURE (psi) AND PENETRATION

RATES (feet/minute) WITH THE BOOSTER COMPRESSOR CONNECTED

PENETRATION RATE (feet/minute)	FEED PRESSURE* (psi)	BIT
4.47	700	44 Standard
2.01	700	48 Standard
4.97	700	48 Standard
4.22	700	48 Standard
2.84	700	Gault Reopened (Relieved)
4.66	700	Gault Reopened (Not Relieved)
6.12	700	1-8 - 21°
4.00	700	1-4 - 25°
4.72	700	2-4 - 25°
2.88	700	2-8 - 25°
6.04	700	3-4 - 18°
2.94	700	3-8 - 18°
2.18	700	Ray Reopened
2.42	700	Gault Reopened (Relieved)

* First 14 holes were drilled at a constant feed pressure to determine which bit performed best at this pressure.

TABLE II

PHASE TWO - COMPARISON OF FEED PRESSURE (psi) AND PENETRATION
RATES (feet/minute) WITH THE BOOSTER COMPRESSOR DISCONNECTED

<u>BIT</u>	<u>FEED PRESSURE</u> <u>(psi)</u>	<u>PENETRATION RATES</u> <u>(feet/minute)</u>
1-8 - 22°	800	6.31 (Dry)
	800	5.90 (Wet)
	900	4.73
	1,000	4.65
2-8 - 24°	800	4.37
	900	4.25
	1,000	4.41
2-4 - 25°	800	4.15
	900	4.39
	1,000	4.50
3-4 - 18°	800	5.45
	900	5.45
	1,000	5.07
3-8 - 18°	800	5.98
	900	5.55
	1,000	6.02
New Standard 8 (Anvil Points Grind*)	700	3.68
	800	3.04
Gault (Resharpened)	700	4.73
	800	4.97
	900	5.37
	1,000	4.86
Gault (Resharpened-cracked insert)	700	4.74
1-8 Standard	900	4.13
	1,100	4.80
	1,300	4.17
	1,200	4.30
	900	4.41
	1,000	4.38
1-4 Standard	900	3.95
	1,000	3.92
	800	3.91
	700	3.19
1-4 - 28°	900	4.23
	1,000	2.15

* Resharpened on Mine bit sharpener.

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PHASE THREE

The third phase of this test encompassed the use of the face jumbo and the bits used in Phase Two at the Arvil Points mine. These bits had been precision resharpened to their approximate original angles. Bits in this section were recorded by their carbide hardness and two angles in degrees. The first of these angles represents the clearance angle measured from vertical and the second represents the clearance angle measured from vertical minus the rake angle (example 1-8 -32° -26°). Figure 1 on page 42 shows a typical four wing drag bit. Horizontal rotary drilling was done on a 23 hole round designed for a commercial size oil shale mining operation. These holes were drilled to a depth of 22 feet. The face cross section indicates that the face is approximately half high grade and half low grade, each with different drilling characteristics.

The high grade material is relatively soft, resilient and highly susceptible to rotary drilling. The best penetration rates are attained in this material. The low grade material is hard and not as susceptible to rotary drilling as the high grade material. Rotary drilling in this material is difficult with poor penetration rates as well as poor bit life. This split face condition makes consistent drilling extremely difficult.

A hole-by-hole breakdown on bit performance can be found on pages 31 through 36. Also included on pages 37 through 39 are horsepower requirements based on actual hydraulic pressure recordings.

PAGE THREE

The third phase of this test encompassed the use of the face
jacks and the bits used in Phase Two at the Anvil Point mine. These
bits had been previously resharpened to their approximate original angles.
Bits in this section were recorded by their carbide hardness and two
angles in degrees. The first of these angles represents the clearance
angle measured from vertical and the second represents the clearance
angle measured from vertical minus the rake angle (example 1-8-32°-32°).
Figure 1 on page 42 shows a typical four wing drag bit. Horizontal rotary
drilling was done on a 2 1/2 inch round designed for a cemental shale oil
shale mining operation. These holes were drilled to a depth of 25 feet.
The face cross section indicates that the face is approximately half high
grade and half low grade, each with different drilling characteristics.

The high grade material is relatively soft, resistant and highly
susceptible to rotary drilling. The best penetration rates were obtained
in this material. The low grade material is hard and not as susceptible
to rotary drilling as the high grade material. Rotary drilling in this
material is difficult with poor penetration rates as well as poor bit life.
This split face condition makes constant drilling extremely difficult.

A hole-by-hole breakdown on bit performance can be found on
pages 31 through 36. Also included on pages 37 through 39 are horsepower
requirements based on actual hydraulic pressure recordings.

Gardner-Denver drill and bit test - horizontal rotary drilling using Gardner-Denver drill jumbo with J.E.D. 1 rotary drill. The rotation and feed pressures are hydraulic gauge pressures in pounds per square inch.

Rotation:

Hard - 110

Soft - 170

Hole Depth: All holes were 22 feet except cut holes which were 24 feet.

1. 1-8 - 32° - 26°

+15 feet Mm* (hard)

Collar - .36

Drill - 8.70 minutes - 2.5 feet/minute (chipped carbides on bit)

Pressures (psi):

Rotation - 1,250

Feed - 900 - 1,000

Air - 82

2. 1-4 - 32° - 26°

+4 feet Mm* (hard)

Collar - .28

Drill - 6.71 minutes - 3.2 feet/minute.

Pressures (psi):

Rotation - 1,100

Feed - 1,000 - 1,200

Air - 86

3. 2-8 - 30° - 22°

+15 feet Mm* (hard)

Collar - .30

Drill - 8.35 minutes - 2.6 feet/minute.

Pressures (psi):

Rotation - 1,200

Feed - 1,000 - 1,200

Air - 82

* Mm = Mahogany marker.

4. 2-8 - 30° - 22°
 +4 feet Mm* (hard)
 Collar - .26
 Drill - 6.20 minutes - 3.5 feet/minute (chipped second carbide)
 Pressures (psi):
 Rotation - 1,000 - 1,200
 Feed - 900 - 1,000
 Air 84
5. 2-4 - 30° - 24°
 -6 feet Mm* (soft) (cut hole)
 Collar - .32
 Drill - 3.46 minutes - 6.35 feet/minute
 Pressures (psi):
 Rotation - 1,000 - 1,400
 Feed - 1,000 - 1,100
 Air 90
6. 2-4 - 30° - 24°
 -14 feet Mm* (soft)
 Collar - .21
 Drill - 4.50 minutes - 4.9 feet/minute (chipped carbide)
 Pressures (psi):
 Rotation - 1,000 - 1,400
 Feed 800 - 1,100
 Air 84
7. 2-4 - 30° - 24°
 -6 feet Mm* (soft seam)
 Collar - .23
 Drill - 4.65 minutes - 4.7 feet/minute
 Pressures (psi):
 Rotation - 1,000 - 1,250
 Feed - 1,000
 Air - 90

* Mm = Mahogany marker.

4. 2-8 - 30° - 22°
 1/4 feet H₂O (sand)

Collar - .35

Drill - 5.25 minutes - 2.5 feet/minute

Pressure (psi):
 Rotation - 1,000 - 1,200
 Feed - 900 - 1,000
 Air 84

5. 2-4 - 30° - 24°

-6 feet H₂O (soft)

Collar - .32

Drill - 3.45 minutes - 6.35 feet/minute

Pressure (psi):
 Rotation - 1,000 - 1,400
 Feed - 1,000 - 1,100
 Air 90

6. 2-4 - 30° - 24°

-14 feet H₂O (soft)

Collar - .31

Drill - 4.50 minutes - 4.8 feet/minute (chipped carbide)

Pressure (psi):
 Rotation - 1,000 - 1,400
 Feed 800
 Air 84

7. 2-4 - 30° - 24°

-6 feet H₂O (soft sand)

Collar - .32

Drill - 4.65 minutes - 4.7 feet/minute

Pressure (psi):
 Rotation - 1,000 - 1,250
 Feed - 1,000
 Air 90

* H₂O = Helogeny water.

8. 2-4 - 30° - 24°
 -8 feet Mm* (cut hole)
 Collar - .28
 Drill - 24 feet - 5.82 minutes - 4.1 feet/minute (chipped second carbide)
 Pressures (psi):
 Rotation - 1,000 - 1,200
 Feed - 800
 Air - 88
9. 3-8 - 22° - 15°
 +2.5 feet Mm* (hard) (cut hole)
 Collar - .21
 Drill - 24 feet - 6.66 minutes - 3.6 feet/minute
 Pressures (psi):
 Rotation - 900 - 1,000
 Feed - 1,000
 Air - 84
10. 3-8 - 22° - 15°
 +15 feet Mm* (hard)
 Collar - .23
 Drill - 6.84 minutes - 3.22 feet/minute
 Pressures (psi):
 Rotation - 1,200 - 1,400
 Feed - 1,000 - 1,100
 Air - 84
11. 3-8 - 22° - 15°
 +7 feet Mm* (hard)
 Collar - .26
 Drill - 6.10 minutes - 3.6 feet/minute
 Pressures (psi):
 Rotation - 1,200 - 1,400
 Feed - 1,000
 Air - 84

* Mm = Mahogany marker.

8. 2-4 - 30° - 24°

-8 feet Mm* (cut hole)

Collar -

Drill - 24 feet - 5.82 minutes - 4.1 feet/minute (chipped second carbid)

Pressures (psi):
Rotation - 1,000 - 1,200
Feed - 800
Air - 88

9. 3-8 - 22° - 12°

+2.5 feet Mm* (hard) (cut hole)

Collar -

Drill - 24 feet - 6.66 minutes - 3.6 feet/minute

Pressures (psi):
Rotation - 900 - 1,000
Feed - 1,000
Air - 84

10. 3-8 - 22° - 12°

+1.5 feet Mm* (hard)

Collar -

Drill - 6.84 minutes - 3.22 feet/minute

Pressures (psi):
Rotation - 1,200 - 1,400
Feed - 1,000 - 1,100
Air - 84

11. 3-8 - 22° - 12°

+7 feet Mm* (hard)

Collar -

Drill - 6.10 minutes - 3.6 feet/minute

Pressures (psi):
Rotation - 1,200 - 1,400
Feed - 1,000
Air - 84

* Mm = Maraganan marker.

12. 3-8 - 22° - 15°
 -15 feet Mn* (soft)
 Collar - .28
 Drill - 4.28 minutes - 5.14 feet/minute
 Pressures (psi):
 Rotation - 1,000 - 1,200
 Feed - 800 - 1,000
 Air - 84
13. 3-8 - 22° - 15°
 -15 feet Mn* (soft)
 Collar - .21
 Drill - 3.19 minutes - 6.89 feet/minute
 Pressures (psi):
 Rotation - 1,100 - 1,400
 Feed - 650 - 800
 Air - 88
14. 3-4 - 24° - 16°
 +15 feet Mn* (hard)
 Collar - .23
 Drill - 7.02 minutes - 3.13 feet/minute
 Pressures (psi):
 Rotation - 1,000 - 1,300
 Feed - 900 - 1,000
 Air - 90
15. 3-4 - 24° - 16°
 +4 feet Mn* (hard)
 Collar - .26
 Drill - 5.64 minutes - 3.9 feet/minute.
 Pressures (psi):
 Rotation - 1,200 - 1,500
 Feed - 1,000 - 1,000
 Air - 88

* Mn = Mahogany marker.

* No = Mainway marker.

Drill - 2.64 minutes - 3.9 feet/minute
 Pressures (psi):
 Rotation - 1,300
 Feed - 1,000
 Air 88

Collar - .28

4 feet M₁ (hard)

15. 3-4 - 24° - 16°

Drill - 7.02 minutes - 3.13 feet/minute
 Pressures (psi):
 Rotation - 1,300
 Feed - 900
 Air 90

Collar - .23

4 feet M₁ (hard)

14. 3-4 - 24° - 16°

Drill - 3.19 minutes - 6.89 feet/minute
 Pressures (psi):
 Rotation - 1,100
 Feed - 850
 Air 88

Collar - .21

15 feet M₁ (soft)

13. 3-8 - 22° - 12°

Drill - 4.28 minutes - 5.14 feet/minute
 Pressures (psi):
 Rotation - 1,000
 Feed - 800
 Air 84

Collar - .28

15 feet M₁ (soft)

12. 3-8 - 22° - 12°

16. 3-4 - 24° - 16°
-3 feet Mm* (hard)
Collar - .25
Drill - 9.59 minutes - 2.29 feet/minute (bit very dull)
Pressures (psi):
Rotation - 1,200 - 1,500
Feed - 750 - 900
Air - 88
17. 1-8 - 32° - 26°
-15 feet Mm* (soft)
Collar - .15
Drill - 3.40 minutes - 6.47 feet/minute
Pressures (psi):
Rotation - 1,200 - 1,400
Feed - 750 - 900
Air - 88
18. 1-4 Standard Reground - 20° - 14°
+15 feet Mm* (hard)
Collar - .23
Drill - 7.32 minutes - 3.0 feet/minute
Pressures (psi):
Rotation - 1,000 - 1,200
Feed - 900 - 1,000
Air 92
19. 1-4 Standard Reground
+4 feet Mm* (hard)
Collar -
Drill - 7.09 minutes - 3.1 feet/minute
Pressures (psi):
Rotation - 1,000 - 1,200
Feed - 900 - 1,000
Air 90

* Mm = Mahogany marker.

16.	3-4 - 30° - 18° - 5 feet (hard) Collar - .15 Drill - 8.59 minutes - 2.29 feet/minute Pressure (psi): Rotation - 1,200 - 1,500 Feed - 750 - 900 Air - 88
17.	1-8 - 32° - 20° - 15 feet (hard) Collar - .15 Drill - 3.40 minutes - 8.45 feet/minute Pressure (psi): Rotation - 1,200 - 1,400 Feed - 750 - 900 Air - 88
18.	1-4 Standard Report - 30° - 14° - 15 feet (hard) Collar - .23 Drill - 7.32 minutes - 3.0 feet/minute Pressure (psi): Rotation - 1,000 - 1,200 Feed - 900 - 1,000 Air - 92
19.	1-4 Standard Report - 40 feet (hard) Collar - Drill - 7.08 minutes - 3.1 feet/minute Pressure (psi): Rotation - 1,000 - 1,200 Feed - 900 - 1,000 Air - 90

* No - Mercury meter.

20. 1-4 Standard Reground - 20° - 14°

-3 feet Mm* (hard)

Collar - .28

Drill - 14.62 minutes - 1.5 feet/minute (bit very dull)

Pressures (psi):

Rotation - 1,100 - 1,400

Feed - 900 - 1,000

Air 90

21. 1-8 Standard Reground - 21° - 15°

-15 feet Mm* (soft)

Collar - .25

Drill - 4.4 minutes - 4.97 feet/minute

Pressures (psi):

Rotation - 1,000

Feed - 650 - 800

Air - 90

* Mm = Mahogany marker.

20. 1-4 Standard Reground - 20° - 14°

-3 Feet Min (hard)

Collar - .28

Drill - 14.82 minutes - 1.5 feet/minute (oil very dull)

Pressures (psi):

Rotation	- 1,100 - 1,400
Feed	- 800 - 1,000
Air	90

21. 1-8 Standard Reground - 21° - 12°

-15 Feet Min (soft)

Collar - .25

Drill - 4.4 minutes - 4.97 feet/minute

Pressures (psi):

Rotation	- 1,000
Feed	- 650 - 800
Air	90

* No - Helium - water

BIT TEST - J.E.D.-1 JUMBO ACTUAL HORSEPOWER REQUIREMENTS

1-8	32°T - 6°R = 26° angle +15 feet Mm*= 17,100 psi - 2.5 feet/minute (chipped carbide)
	Rotation Pressure: hydraulic - 1,250 psi torque - 631 foot-lbs - 12.0 H.P.
	Feed Pressure: hydraulic - 1,000 psi thrust - 9,045 lbs - .68 H.P.
1-4	32°T - 6°R = 26° angle +4 feet Mm*= 17,100 psi - 3.28 feet/minute (broken carbide)
	Rotation Pressure: hydraulic - 1,100 psi torque - 532 foot-lbs - 10.1 H.P.
	Feed Pressure: hydraulic - 1,200 psi thrust -13,567 lbs - 1.34 H.P.
2-8	30°T - 6°R = 22° angle + 15 feet Mm*= 17,100 psi - 2.63 feet/minute
	Rotation Pressure: hydraulic - 1,200 psi torque - 598 foot-lbs - 11.39 H.P.
	Feed Pressure: hydraulic - 1,200 psi thrust -13,567 lbs - 1.34 H.P.
2-8	30°T - 8°R = 22° angle +4 feet Mm*= 17,100 psi - 3.55 feet/minute (two broken carbides)
	Rotation Pressure: hydraulic - 1,200 psi torque - 598 foot-lbs - 11.39 H.P.
	Feed Pressure: hydraulic - 1,000 psi thrust - 9,045 lbs - .97 H.P.
2-4	30°T - 6°R = 24° angle -6 feet Mm*= 11,700 psi - 6.36 feet/minute
	Rotation Pressure: hydraulic - 1,400 psi torque - 731 foot-lbs - 20.88 H.P.
	Feed Pressure: hydraulic - 1,100 psi thrust -11,306 lbs - 1.10 H.P.
2-4	30°T - 6°R = 24° angle -14 feet Mm*= 7,300 psi - 4.89 feet/minute (broken carbide)
	Rotation Pressure: hydraulic - 1,400 psi torque - 731 foot-lbs - 20.88 H.P.
	Feed Pressure: hydraulic - 900 psi thrust - 6,784 lbs - 1.00 H.P.
2-4	30°T - 6°R = 24° angle -6 feet Mm*= 11,700 psi - 4.73 feet/minute
	Rotation Pressure: hydraulic - 1,250 psi torque - 631 foot-lbs - 12.00 H.P.
	Feed Pressure: hydraulic - 1,000 psi thrust - 9,045 lbs - 2.11 H.P.

* Mm = Mahogany marker.

BIT TEST - J.E.D.-1 JUNG0 ACTUAL HORSEPOWER REQUIREMENTS

1-8	32°T - 6°R = 36° angle + 1/2 foot lbs = 17,100 psi - 2.2 feet/minute (chipped carbide)	Rotation Pressure: Hydraulic - 1,350 psi torque - 631 foot-lbs - 12.0 H.P. Feed Pressure: Hydraulic - 1,000 psi thrust - 9,042 lbs - 68 H.P.
1-4	32°T - 6°R = 36° angle + 1/2 foot lbs = 17,100 psi - 3.38 feet/minute (broken carbide)	Rotation Pressure: Hydraulic - 1,100 psi torque - 532 foot-lbs - 10.1 H.P. Feed Pressure: Hydraulic - 1,200 psi thrust - 13,267 lbs - 1.34 H.P.
2-8	30°T - 6°R = 33° angle + 1/2 foot lbs = 17,100 psi - 2.63 feet/minute	Rotation Pressure: Hydraulic - 1,200 psi torque - 598 foot-lbs - 11.39 H.P. Feed Pressure: Hydraulic - 1,200 psi thrust - 13,267 lbs - 1.34 H.P.
2-8	30°T - 6°R = 33° angle + 1/2 foot lbs = 17,100 psi - 3.35 feet/minute (two broken carbides)	Rotation Pressure: Hydraulic - 1,200 psi torque - 598 foot-lbs - 11.39 H.P. Feed Pressure: Hydraulic - 1,000 psi thrust - 9,042 lbs - 97 H.P.
2-4	30°T - 6°R = 34° angle - 1/2 foot lbs = 11,700 psi - 6.38 feet/minute	Rotation Pressure: Hydraulic - 1,400 psi torque - 731 foot-lbs - 20.88 H.P. Feed Pressure: Hydraulic - 1,100 psi thrust - 11,308 lbs - 1.10 H.P.
2-4	30°T - 6°R = 34° angle - 1/2 foot lbs = 11,700 psi - 4.89 feet/minute (broken carbide)	Rotation Pressure: Hydraulic - 1,400 psi torque - 731 foot-lbs - 20.88 H.P. Feed Pressure: Hydraulic - 900 psi thrust - 6,786 lbs - 1.00 H.P.
2-4	30°T - 6°R = 34° angle - 1/2 foot lbs = 11,700 psi - 4.73 feet/minute	Rotation Pressure: Hydraulic - 1,150 psi torque - 631 foot-lbs - 12.00 H.P. Feed Pressure: Hydraulic - 1,000 psi thrust - 9,042 lbs - 2.11 H.P.

* Mm = Mahogany marker.

30°T - 5°R = 24° angle - 8 feet H₂O = 12,000 gal - 4.12 feet/minute
(broken cartridge)

Rotation Pressure: Hydraulic - 1,200 gal
torque - 598 foot-lbs - 17.08 H.P.
Feed Pressure: Hydraulic - 800 gal
thrust - 4,523 lbs - 3.56 H.P.

27°T - 7°R = 12° angle - 3 feet H₂O = 12,000 gal - 3.61 feet/minute

Rotation Pressure: Hydraulic - 1,100 gal
torque - 532 foot-lbs - 10.12 H.P.
Feed Pressure: Hydraulic - 1,000 gal
thrust - 2,042 lbs - 1.98 H.P.

24°T - 7°R = 12° angle - 4.5 feet H₂O = 17,100 gal - 3.22 feet/minute

Rotation Pressure: Hydraulic - 1,400 gal
torque - 731 foot-lbs - 12.32 H.P.
Feed Pressure: Hydraulic - 1,100 gal
thrust - 1,100 lbs - 1.10 H.P.

22°T - 7°R = 12° angle - 7 feet H₂O = 17,000 gal - 3.6 feet/minute

Rotation Pressure: Hydraulic - 1,400 gal
torque - 731 foot-lbs - 12.3 H.P.
Feed Pressure: Hydraulic - 1,000 gal
thrust - 2,042 lbs - 1.98 H.P.

22°T - 7°R = 12° angle - 12 feet H₂O = 7,300 gal - 5.1 feet/minute

Rotation Pressure: Hydraulic - 1,200 gal
torque - 598 foot-lbs - 17.08 H.P.
Feed Pressure: Hydraulic - 1,000 gal
thrust - 2,042 lbs - 1.98 H.P.

22°T - 7°R = 12° angle - 15 feet H₂O = 7,300 gal - 6.9 feet/minute

Rotation Pressure: Hydraulic - 1,100 gal
torque - 532 foot-lbs - 12.18 H.P.
Feed Pressure: Hydraulic - 800 gal
thrust - 4,523 lbs - 3.56 H.P.

24°T - 8°R = 16° angle - 15 feet H₂O = 17,100 gal - 3.13 feet/minute

Rotation Pressure: Hydraulic - 1,300 gal
torque - 665 foot-lbs - 12.62 H.P.
Feed Pressure: Hydraulic - 1,000 gal
thrust - 2,042 lbs - 1.98 H.P.

24°T - 8°R = 16° angle - 17 feet H₂O = 17,100 gal - 3.9 feet/minute

Rotation Pressure: Hydraulic - 1,200 gal
torque - 598 foot-lbs - 17.08 H.P.
Feed Pressure: Hydraulic - 1,000 gal
thrust - 2,042 lbs - 1.98 H.P.

3-4 24°T - 8°R = 16° angle -3 feet Mm*= 19,000 psi - 2.29 feet/minute

Rotation Pressure: hydraulic - 1,500 psi
torque - 797 foot-lbs - 15.18 H.P.

Feed Pressure: hydraulic - 1,000 psi
thrust - 9,045 Lbs - .63 H.P.

1-8 32°T - 6°R = 26° angle -15 feet Mm*= 7,300 psi - 6.47 feet/minute

Rotation Pressure: hydraulic - 1,400 psi
torque - 731 foot-lbs - 24.88 H.P.

Feed Pressure: hydraulic - 900 psi
thrust - 6,784 lbs - 1.33 H.P.

1-4 20°T - 6°R = 14° angle +15 feet Mm*= 17,100 psi - 3.01 feet/minute

Rotation Pressure: hydraulic - 1,200 psi
torque - 598 foot-lbs - 11.39 H.P.

Feed Pressure: hydraulic - 1,000 psi
thrust - 9,045 lbs - .83 H.P.

1-4 20°T - 6°R = 14° angle +4 feet Mm*= 17,000 psi - 3.16 feet/minute

Rotation Pressure: hydraulic - 1,200 psi
torque - 598 foot-lbs - 11.39 H.P.

Feed Pressure: hydraulic - 1,000 psi
thrust - 9,045 lbs - .86 H.P.

1-4 20°T - 6°R = 14° angle -3 feet Mm*= 17,000 psi - 1.5 feet/minute

Rotation Pressure: hydraulic - 1,400 psi
torque - 731 foot-lbs - 13.9 H.P.

Feed Pressure: hydraulic - 1,100 psi
thrust - 11,306 lbs - .51 H.P.

1-8 21°T - 7°R = 15° angle -15 feet Mm*= 7,300 psi - 4.98 feet/minute

Rotation Pressure: hydraulic - 1,000 psi
torque - 465 foot-lbs - 13.28 H.P.

Feed Pressure: hydraulic - 800 psi
thrust - 4,523 lbs - .68 H.P.

* Mm = Mahogany marker.

3-4	25°T - 5°R = 16° angle - 3 feet H ₂ O = 12,000 psi - 2.22 feet/minute	
	Rotation Pressure: Hydraulic - 1,500 psi	
	Torque - 737 foot-lbs - 12.18 H.P.	
	Feed Pressure: Hydraulic - 1,000 psi	
	Thrust - 9,042 lbs - .63 H.P.	
1-8	32°T - 6°R = 16° angle - 12 feet H ₂ O = 7,300 psi - 6.47 feet/minute	
	Rotation Pressure: Hydraulic - 1,400 psi	
	Torque - 731 foot-lbs - 12.88 H.P.	
	Feed Pressure: Hydraulic - 900 psi	
	Thrust - 6,786 lbs - 1.22 H.P.	
1-4	30°T - 6°R = 14° angle - 12 feet H ₂ O = 17,100 psi - 3.01 feet/minute	
	Rotation Pressure: Hydraulic - 1,300 psi	
	Torque - 598 foot-lbs - 11.39 H.P.	
	Feed Pressure: Hydraulic - 1,000 psi	
	Thrust - 9,042 lbs - .83 H.P.	
1-4	30°T - 6°R = 14° angle - 4 feet H ₂ O = 17,000 psi - 2.16 feet/minute	
	Rotation Pressure: Hydraulic - 1,300 psi	
	Torque - 598 foot-lbs - 11.39 H.P.	
	Feed Pressure: Hydraulic - 1,000 psi	
	Thrust - 9,042 lbs - .86 H.P.	
1-4	30°T - 6°R = 14° angle - 3 feet H ₂ O = 17,000 psi - 1.5 feet/minute	
	Rotation Pressure: Hydraulic - 1,400 psi	
	Torque - 731 foot-lbs - 12.8 H.P.	
	Feed Pressure: Hydraulic - 1,100 psi	
	Thrust - 11,306 lbs - .51 H.P.	
1-8	31°T - 7°R = 12° angle - 12 feet H ₂ O = 7,300 psi - 4.98 feet/minute	
	Rotation Pressure: Hydraulic - 1,000 psi	
	Torque - 465 foot-lbs - 13.28 H.P.	
	Feed Pressure: Hydraulic - 800 psi	
	Thrust - 4,523 lbs - .68 H.P.	

* H₂O = Mahogany water.

SUMMARY:

The third phase dealt with the testing of precision sharpened drag bits on the Anvil Points mine face jumbo. These bits were used to drill horizontal holes for a commercial size round. The biggest problem in the drilling of a face round is the difference in drilling characteristics from high to low grade oil shale. The face round is half high and half low grade.

Results from this phase indicate that rotary drilling of high grade oil shale attains good penetration rates. Slower penetration rates were attained in the low grade shale. Bit life in the high grade shale was far better than in the low grade shale.

In this test, chipping of the carbides in certain bits became a problem, although it did not seem to slow down the penetration rates.

The horsepower requirements for each individual hole are listed on pages 37 through 39. These are somewhat low compared to previous tests at other oil shale mines.

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The third phase dealt with the testing of precision sharpened drag bits on the Anvil Point mine face (Jumbo). These bits were used to drill horizontal holes for a commercial size round. The biggest problem in the drilling of a face round is the difference in drilling characteristics from high to low grade oil shale. The face round is half high and half low grade.

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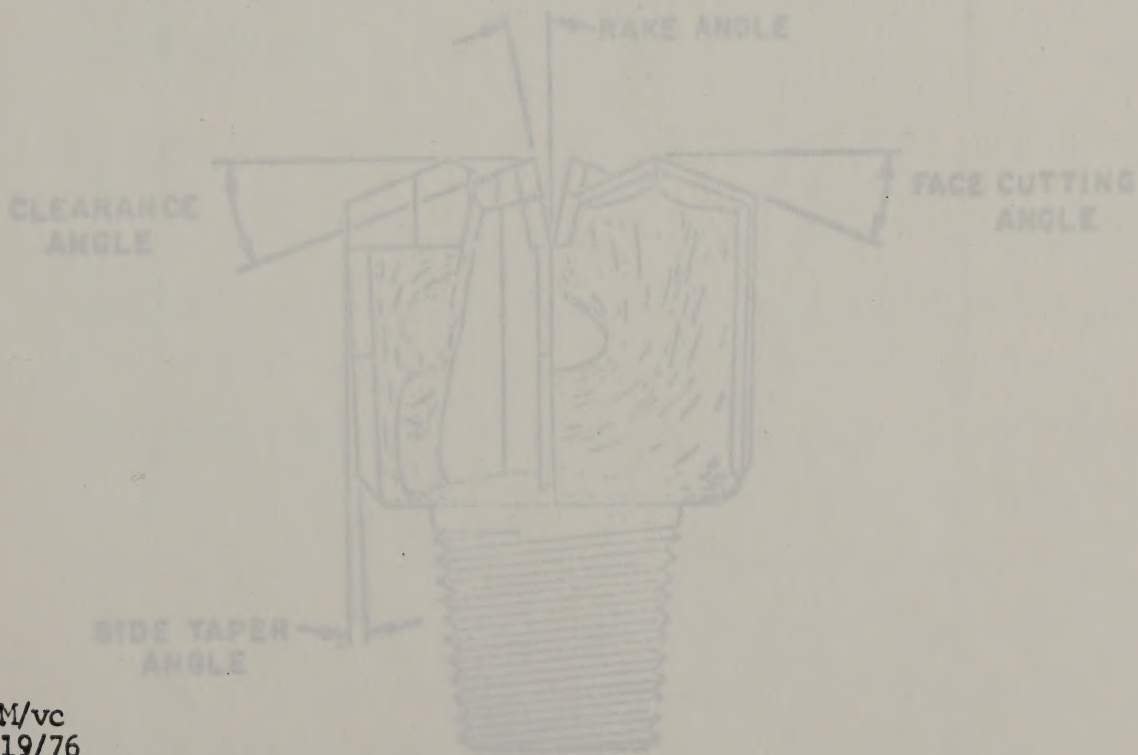
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CONCLUSION:

The drill and bit test indicated that straight rotary drilling with conventional drag bits attained the best penetration rates. The rotary percussion drilling, using the Mission Megadrill, performed poorly which was mainly due to the lack of rotary percussion type bits or some other bit type that would hold up under percussion drilling. Future testing with rotary percussion type drilling equipment should be looked into.

Feed pressure control indicated that the bit's clearance angle is the governing factor in the amount of feed pressure needed to attain the best penetration rates. Different bits with different clearance angles performed best at varying pressures. Some bits performed well at all feed pressures.



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FIGURE 1

4 INCH DRAG BIT

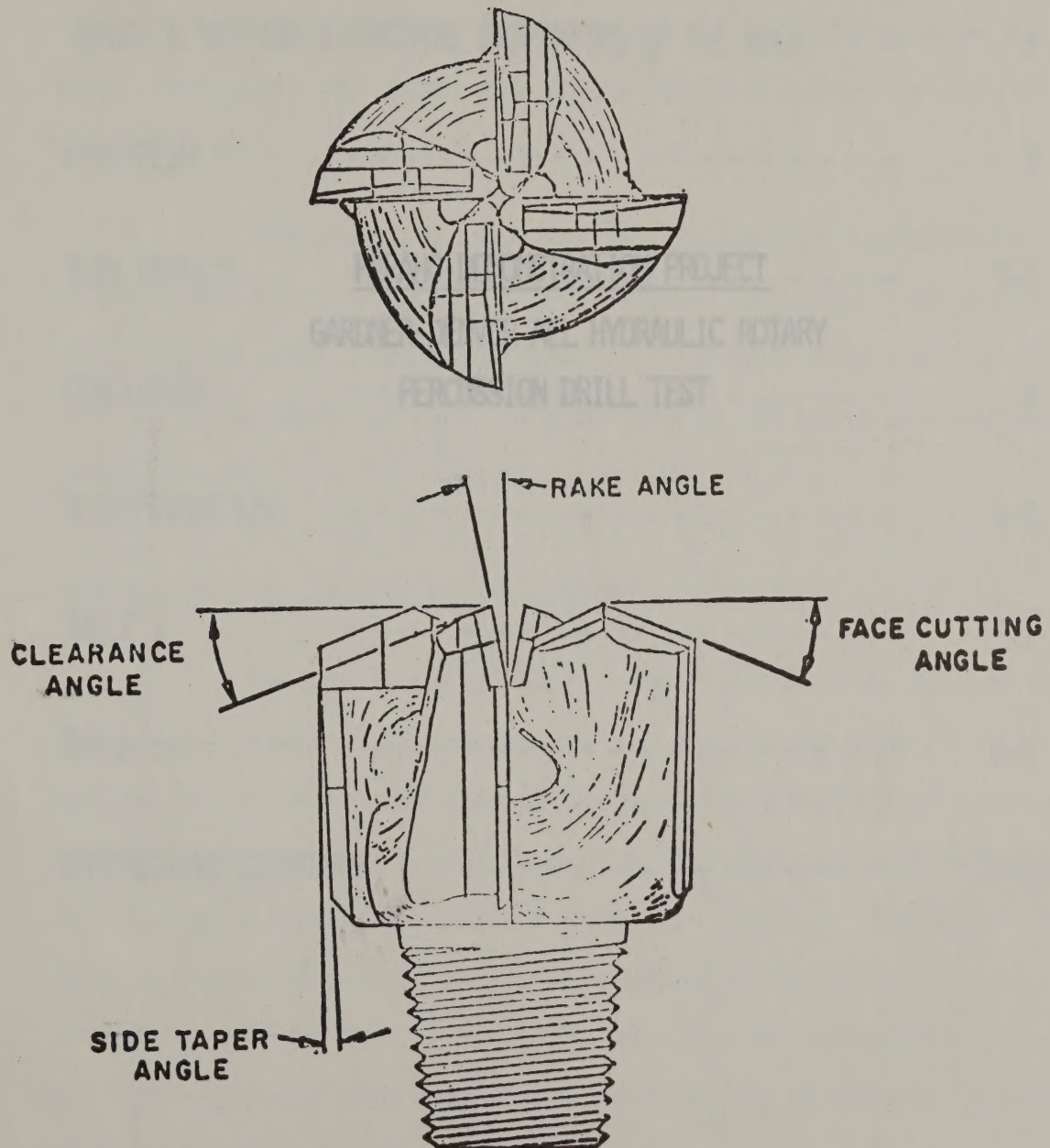


FIGURE 1

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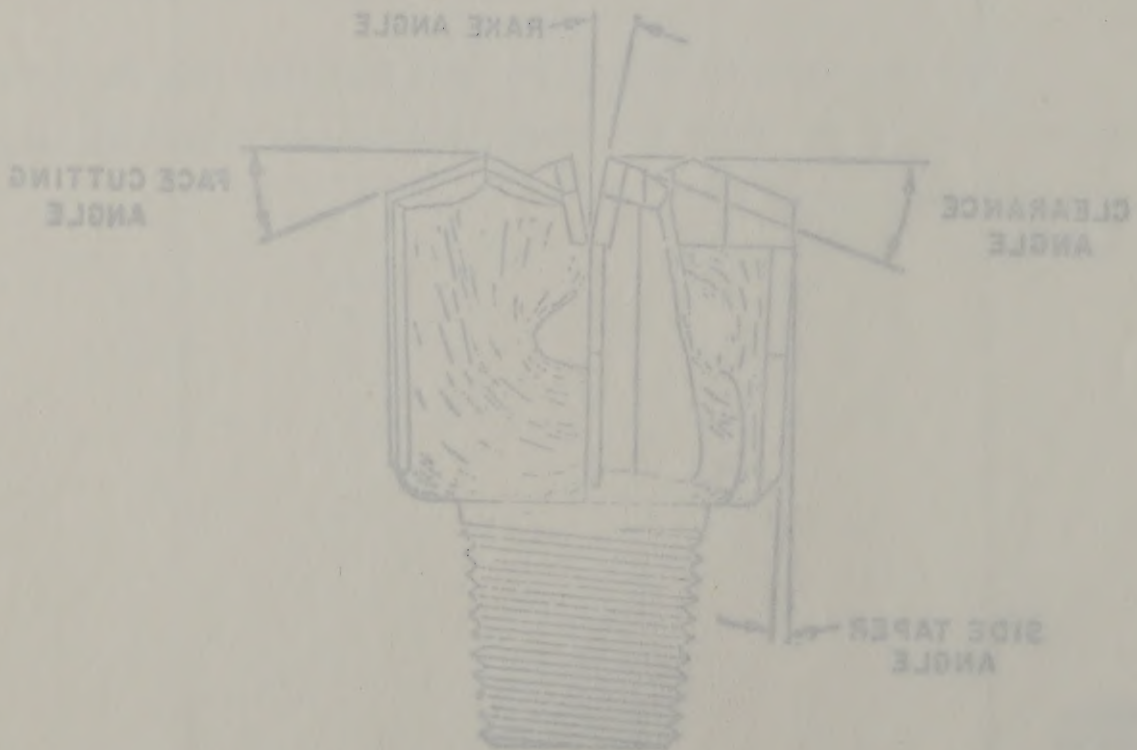


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PARADO DEMONSTRATION PROJECT

GARDNER-DENVER ALL HYDRAULIC ROTARY

PERCUSSION DRILL TEST

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GARDNER-DENVER ALL HYDRAULIC ROTARY PERCUSSION DRILL TEST

INTRODUCTION:

For two weeks in January of 1976, Gardner-Denver Company furnished a prototype all hydraulic rotary percussion drill jumbo for testing at the Paraho Demonstration Project's Anvil Points mine near Rifle, Colorado. The total cost of the test was assumed by the Gardner-Denver Company.

This test was conducted in an area of the mine where a complete section of the face was accessible. Both high grade (soft) and low grade (hard) zones were drilled. Gardner-Denver came prepared with an ample supply of bits, both percussion and rotary percussion in sizes up to 4".

PHYSICAL SETTING AND PHYSICAL PROPERTIES OF THE ROCK:

The rich shale drilled in this test was 7 to 15 feet below the Mahogany marker. Oil content of this rock ranges from 21 to 86 gallons per ton with rock compressive strengths ranging from 8,000 to 16,500 pounds per square inch. The rich shale is weak rock having a low modulus of elasticity and a high Poisson's ratio. Percussion energy from percussion or rotary percussion drilling is apparently easily dissipated in this type of rock. For this reason, penetration rates in the rich shale are lower for percussion or rotary percussion drilling than for straight rotary drilling.

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The rich shale drilled in this test was 7 to 15 feet below the Mahogany member. Oil content of this rock ranges from 21 to 86 gallons per ton with rock compressive strengths ranging from 8,000 to 16,500 pounds per square inch. The rich shale is weak rock having a low modulus of elasticity and a high Poisson's ratio. Percussion energy from percussion or rotary percussion drilling is apparently easily dissipated in this type of rock. For this reason, penetration rates in the rich shale are lower for percussion or rotary percussion drilling than for straight rotary drilling.

The lean shale zones predominately lie above and immediately below the Mahogany marker. The lean shale is strong having a high modulus of elasticity and a low Poisson's ratio. The lean zones drilled in this test are near the Mahogany marker. Oil content of this rock ranges from 9 to 16 gallons per ton with rock compressive strengths ranging from 18,000 to 24,000 pounds per square inch.

Rotary percussion drilling in lean shale zones attains higher penetration rates than straight rotary or percussion drilling.

EQUIPMENT:

Gardner-Denver Company furnished a Universal -3 diesel powered jumbo carrier equipped with electric powered hydraulic systems to test two HPR-1 all hydraulic rotary percussion drills. The electric motors used to power the hydraulic systems are each rated at 75 horsepower. Each drill develops 400,000 to 500,000 foot pounds of energy per minute, depending on the percussion stroke setting. The percussion function of the drill machine can be adjusted to one of four settings. These settings with approximate blows per minute, foot pounds per blow and foot pounds per minute are found in Table I.

TABLE I

<u>GAUGE SETTING HYDRAULIC PRESSURE IN LBS/SQ INCH</u>	<u>BLOWS PER MINUTE</u>	<u>FOOT POUNDS PER BLOW</u>	<u>FOOT POUNDS PER MINUTE</u>
1,500	2,500	200	500,000
1,000	3,000	166	498,000
750	3,500	133	465,500
0	4,000	100	400,000

The lean shale zones predominate above and immediately below the Mahogany marker. The lean shale is strong having a high modulus of elasticity and a low Poisson's ratio. The lean zones drilled in this test are near the Mahogany marker. Oil content of this rock ranges from 9 to 16 gallons per ton with rock compressive strengths ranging from 18,000 to 24,000 pounds per square inch.

Rotary percussion drilling in lean shale zones attains higher penetration rates than straight rotary or percussion drilling.

CONCLUSIONS

Gardner-Denver Company furnished a Universal-3 diesel powered pump carrier equipped with electric powered hydraulic systems to test two RPT-1 all hydraulic rotary percussion drills. The electric motors used to power the hydraulic systems are each rated at 75 horsepower. Each drill develops 400,000 to 500,000 foot pounds of energy per minute, depending on the percussion stroke setting. The percussion function of the drill machine can be adjusted to one of four settings. These settings with approximate blow per minute, foot pounds per blow and foot pounds per minute are found in Table I.

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PERCUSSION STROKE SETTING IN INCHES	HYDRAULIC PRESSURE IN PSI	BLOWS PER MINUTE	FOOT POUNDS PER BLOW	FOOT POUNDS PER MINUTE
1.500	1,500	2,500	200	500,000
1.000	3,000	3,000	166	498,000
.750	3,500	3,500	133	462,500
0	4,000	4,000	100	400,000

TEST RESULTS: Gardner-Denver indicated that the jumbo and drills, as a unit, were not specifically designed for drilling in oil shale. Although the unit was not designed for drilling in oil shale, it is felt that hydraulic rotary percussion drilling will have some type of application in the development of oil shale.

Resharpening of bits was possible as Gardner-Denver furnished a bit grinding machine. This made testing of various bits with different angles possible.

TEST RESULTS:

As a whole, penetration rates attained in this test were equivalent to those of previously tested rotary percussion drills. Table II (pages 6,7,8 & 9) lists various sized bits tested in different shale horizons (+ Mahogany marker) with the four percussion stroke settings. The bits are both percussion and rotary percussion type ranging in size from 2" to 4". Graphs were plotted with respect to the four percussion stroke settings as well as penetration rates versus oil shale grades. Along with these grades are the approximate corresponding compressive strengths. These are included on pages 10, 11, 12 and 13. All the penetration rates on these graphs are for 4" bits. Most of the larger bits tested (3" to 4") were of the percussion type. After testing of the percussion bits, some of them were reground to simulate rotary percussion type bits. Overall, rotary percussion type bits attained the best penetration rates but a few percussion type bits did drill as fast.

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TEST RESULTS:

The best penetration rates in all areas drilled (hard and soft) were attained while drilling on percussion stroke settings of 1,500 and 1,000 psi. These two settings have the fewest blows per minute but the most foot pounds per blow. This would indicate that there is a direct relationship between the amount of energy introduced and the penetration rates attained.

The bit type made a large difference in the penetration rate. Percussion bits reground to simulate rotary percussion type bits attained the best penetration rates. More testing with different bit angles needs to be done in order to substantiate the optimum of angles for the drilling of oil shale.

CONCLUSION:

The Gardner-Denver HPR-1 all hydraulic rotary percussion drill performed well in the low grade shale zones but penetration rates in the high grade shale zones were poor. Overall drill potential seems to be good but combined with inadequate bit design, overall penetration rates do not meet those of conventional rotary drilling.

RECOMMENDATIONS:

Gardner-Denver has a larger prototype all hydraulic rotary percussion drill in the building stages. It is suggested that when this unit is available that it be tested in the drilling of oil shale.

TEST RESULTS:

The best penetration rates in all areas drilled (hard and soft) were attained while drilling on percussion stroke settings of 1,500 and 1,000 psi. These two settings have the lowest blows per minute but the most foot pounds per blow. This would indicate that there is a direct relationship between the amount of energy introduced and the penetration rates attained.

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CONCLUSION:

The Gardner-Denver HR-1 all hydraulic rotary percussion drill performed well in the low grade shale zones but penetration rates in the high grade shale zones were poor. Overall drill potential seems to be good but combined with inadequate bit design, overall penetration rates do not meet those of conventional rotary drilling.

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TABLE II

Bit design, with respect to rotary percussion type for drilling experiments in oil shale, is far behind drill development. It is recommended that a major bit manufacturer be persuaded to enter these experiments with new bit designs.

BIT SIZE	ANGLE (Degrees)	TIME TO PENETRATION (Minutes)	ROTARY PERCUSSION RATE (Revs./Minute)	PERCUSSION RATE (Blows/Minute)	DEPTH (Feet)
2"	-3	2.04	5.58	2.08	750
2"	+1	2.35	5.11	1.81	750
2"	-1	2.10	5.71	2.02	1,000
2"	-2	1.85	6.49	2.30	1,000
2"	-7	2.20	5.45	1.93	1,000
2"	-11	2.38	5.04	1.79	1,000
2"	-15	4.57	2.63	.93	1,000
2"	-15	5.21	2.30	.81	750
2"	-11	2.55	4.71	1.68	750
3"	-5	3.84	3.13	2.03	750
3"	-5	3.76	3.19	2.07	1,000
3"	-3	3.72	3.73	2.42	1,500
3"	-3.5	2.50	4.80	3.12	1,500
3"	-3.5	2.28	5.31	3.45	1,000
3"	-3.5	2.66	4.51	2.93	750
3"	-3.5	3.13	3.83	2.49	-0-
3"	0	3.23	3.71	2.41	1,500
3"	0	2.90	3.14	2.04	1,000
3"	0	3.30	3.66	2.37	750
3"	0	4.34	2.78	1.79	-0-
3"	+1.5	3.70	3.24	2.11	1,500

* Bits are both percussion and rotary percussion type.

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drilling experiments in oil shale, is far behind drill development.

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TABLE II

<u>BIT* SIZE</u>	<u>+ MAHOGANY - MARKER</u>	<u>TIME TO DRILL 12' (Minutes)</u>	<u>FEET PER MINUTE</u>	<u>CONVERSION TO 4" BIT TIME (Feet/Minute)</u>	<u>PERCUSSION HAMMER STROKE SETTING</u>
2"	-7	1.85	6.49	2.30	750
2"	-3	2.04	5.88	2.08	750
2"	+1	2.35	5.11	1.81	750
2"	-1	2.10	5.71	2.02	1,000
2"	-2	1.85	6.49	2.30	1,000
2"	-7	2.20	5.45	1.93	1,000
2"	-11	2.38	5.04	1.78	1,000
2"	-15	4.57	2.63	.93	1,000
2"	-15	5.21	2.30	.81	750
2"	-11	2.55	4.71	1.68	750
3"	-5	3.84	3.13	2.03	750
3"	-5	3.76	3.19	2.07	1,000
3"	-5	3.22	3.73	2.42	1,500
3"	-3.5	2.50	4.80	3.12	1,500
3"	-3.5	2.26	5.31	3.45	1,000
3"	-3.5	2.66	4.51	2.93	750
3"	-3.5	3.13	3.83	2.49	-0-
3"	0	3.23	3.71	2.41	1,500
3"	0	2.90	3.14	2.04	1,000
3"	0	3.30	3.64	2.37	750
3"	0	4.34	2.76	1.79	-0-
3"	+1.5	3.70	3.24	2.11	1,500

* Bits are both percussion and rotary percussion type.

TABLE II

BIT* SIZE	+ MANDRAY - HANGER	TIME TO DRILL 12' (Minutes)	FEET PER MINUTE	CONVERSION TO 4" BIT TIME (Feet/Minute)	PERCUSION HAMMER STROKE SETTING
3"	-7	1.82	6.49	2.30	750
3"	-3	2.04	5.88	2.08	750
3"	+1	2.32	5.11	1.81	750
3"	-1	2.10	5.71	2.02	1,000
3"	-2	1.82	6.49	2.30	1,000
3"	-7	2.20	5.45	1.93	1,000
3"	-11	2.38	5.04	1.78	1,000
3"	-12	4.27	2.83	.93	1,000
3"	-12	2.21	5.30	.81	750
3"	-11	2.22	4.71	1.68	750
3"	-2	3.84	3.13	2.03	750
3"	-2	3.78	3.19	2.07	1,000
3"	-2	3.22	3.73	2.42	1,200
3"	-3.2	2.20	4.80	3.12	1,200
3"	-3.2	2.26	5.31	3.42	1,000
3"	-3.2	2.66	4.21	2.93	750
3"	-3.2	3.12	3.83	2.49	-0-
3"	0	3.23	3.71	2.41	1,200
3"	0	2.20	3.14	2.04	1,000
3"	0	3.30	3.64	2.37	750
3"	0	4.34	2.76	1.73	-0-
3"	+1.2	3.70	3.24	2.11	1,200

* Bits are both percussion and rotary percussion type.

TABLE II
(Continued)

<u>BIT* SIZE</u>	<u>+ MAHOGANY MARKER</u>	<u>TIME TO DRILL 12' (Minutes)</u>	<u>FEET PER MINUTE</u>	<u>CONVERSION TO 4" BIT TIME (Feet/Minute)</u>	<u>PERCUSSION HAMMER STROKE SETTING</u>
4"	+1	3.92	3.06	3.06	1,500
4"	+1	3.95	3.04	3.04	1,500
4"	-6	3.72	3.23	3.23	1,500
4"	+1	4.92	2.44	2.44	1,500
4"	-14	6.45	1.86	1.86	1,500
4"	-3	3.50	3.43	3.43	1,500
2½"	-14	2.65	4.53	2.24	1,500
2½"	-14	3.36	3.57	1.77	1,000
2½"	-14	3.46	3.47	1.72	750
2½"	-14	3.43	3.50	1.73	-0-
2½"	-11	2.33	5.15	2.55	1,500
2½"	-11	2.64	4.54	2.25	1,000
2½"	-11	2.60	4.62	2.29	750
2½"	-11	3.78	3.17	1.57	-0-
2½"	-8	2.80	4.28	2.12	1,500
2½"	-8	3.19	3.76	1.86	750
2½"	-8	3.60	3.33	1.65	-0-
2½"	-8	2.07	5.80	2.87	1,000
3"	-1	3.37	3.56	2.31	1,000
3"	-1	3.52	3.41	2.22	750
3"	-1	4.05	2.96	1.92	-0-
3"	-3	3.10	3.87	2.51	1,500

* Bits are both percussion and rotary percussion type.

TABLE II
(Continued)

PERCUSSION WATER STROKE SETTING	CONVERSION TO 4" BIT TIME (Feet/Minute)	FEET PER MINUTE	TIME TO DRILL 12' (Minutes)	+ MASONRY - WATER	BIT SIZE
1,500	3.06	3.06	3.92	+1	4"
1,500	3.04	3.04	3.92	+1	4"
1,500	3.23	3.23	3.72	-6	4"
1,500	2.44	2.44	4.92	+1	4"
1,500	1.86	1.86	6.42	-14	4"
1,500	3.43	3.43	3.20	-3	4"
1,500	2.24	4.22	2.62	-14	2 1/2"
1,000	1.77	3.27	3.36	-14	2 1/2"
750	1.72	3.47	3.46	-14	2 1/2"
-0-	1.72	3.20	3.42	-14	2 1/2"
1,500	2.22	2.12	2.22	-11	2 1/2"
1,000	2.22	4.24	2.64	-11	2 1/2"
750	2.22	4.62	2.60	-11	2 1/2"
-0-	1.27	3.17	3.78	-11	2 1/2"
1,500	2.12	4.28	2.80	-8	2 1/2"
750	1.86	3.76	3.12	-8	2 1/2"
-0-	1.62	3.22	3.60	-8	2 1/2"
1,000	2.87	2.80	2.07	-8	2 1/2"
1,000	2.21	3.26	3.27	-1	3"
750	2.22	3.41	3.22	-1	3"
-0-	1.92	2.96	4.02	-1	3"
1,500	2.21	2.87	3.10	-3	3"

* Bits are both percussive and rotary percussive type.

TABLE II
(Continued)

<u>BIT* SIZE</u>	<u>+ MAHOGANY MARKER</u>	<u>TIME TO DRILL 12' (Minutes)</u>	<u>FEET PER MINUTE</u>	<u>CONVERSION TO 4" BIT TIME (Feet/Minute)</u>	<u>PERCUSSION HAMMER STROKE SETTING</u>
3"	-3	2.66	4.51	2.93	1,000
3"	-3	2.63	4.56	2.96	750
3"	-3	3.15	3.81	2.48	-0-
3"	-7	2.33	5.15	3.35	1,500
3"	-7.5	2.42	4.96	3.22	1,000
3"	-7.5	2.62	4.58	2.98	750
3"	-7.5	3.50	3.43	2.23	-0-
3"	-11	2.78	4.32	2.80	1,500
3"	-11	2.87	4.18	2.72	1,000
3"	-11	3.23	3.72	2.42	750
3"	-11	4.24	2.83	1.84	-0-
3"	-15	3.78	3.17	2.06	1,500
3"	-15	4.05	2.96	1.92	1,000
3"	-15	4.80	2.50	1.62	750
3"	-15	6.63	1.81	1.18	-0-
4"	-1	3.50	3.43	3.43	1,500
4"	-1	4.25	2.82	2.82	1,000
4"	-1	4.28	2.80	2.80	750
4"	-1	4.90	2.45	2.45	-0-
4"	-3	3.34	3.59	3.59	1,500
4"	-3	3.00	4.00	4.00	1,000

* Bits are both percussion and rotary percussion type.

TABLE II
(Continued)

PERCUSSION HAMMER SETTING	CONVERSION TO 6" BIT TIME (Feet/Minute)	FEET PER MINUTE	TIME TO DRILL 12' (Minutes)	+ MECHANICAL WALKER	BIT SIZE
1,000	2.93	4.21	2.66	-3	3"
750	2.96	4.26	2.63	-3	3"
-0-	2.68	3.81	3.12	-3	3"
1,500	3.32	2.12	2.33	-7	3"
1,000	2.22	4.96	2.42	-7.2	3"
750	2.98	4.28	2.62	-7.2	3"
-0-	2.23	3.43	3.20	-7.2	3"
1,500	2.80	4.22	2.78	-11	3"
1,000	2.72	4.18	2.87	-11	3"
750	2.42	3.72	3.23	-11	3"
-0-	1.84	2.82	4.24	-11	3"
1,500	2.06	3.17	3.78	-12	3"
1,000	1.92	2.96	4.02	-12	3"
750	1.62	2.20	4.80	-12	3"
-0-	1.18	1.81	6.62	-12	3"
1,500	2.43	3.43	3.20	-1	4"
1,000	2.62	2.82	4.22	-1	4"
750	2.80	2.80	4.28	-1	4"
-0-	2.42	2.42	4.90	-1	4"
1,500	3.29	3.29	3.24	-3	4"
1,000	4.00	4.00	2.00	-3	4"

* Bits are both percussion and rotary percussion type.

TABLE II
(Continued)

<u>BIT* SIZE</u>	<u>+ MAHOGANY MARKER</u>	<u>TIME TO DRILL 12' (Minutes)</u>	<u>FEET PER MINUTE</u>	<u>CONVERSION TO 4" BIT TIME (Feet/Minute)</u>	<u>PERCUSSION HAMMER STROKE SETTING</u>
4"	-3	3.32	3.61	3.61	750
4"	-3	4.12	2.91	2.91	-0-
4"	-7	3.90	3.08	3.08	1,500
4"	-6	4.20	2.85	2.85	1,000
4"	-6	4.47	2.68	2.68	750
4"	-6	5.23	2.29	2.29	-0-
4"	-10	4.42	2.71	2.71	1,500
4"	-10	5.05	2.38	2.38	1,000
4"	-10	4.80	2.50	2.50	750
4"	-10	6.50	1.85	1.85	-0-
4"	-15	8.00	1.50	1.50	1,500

Conversion factor to 4" bit penetration rates: 3" to 4" x .650

2½" to 4" x .495

2¼" to 4" x .442

2" to 4" x .354

* Bits are both percussion and rotary percussion type.

TABLE II
(Continued)

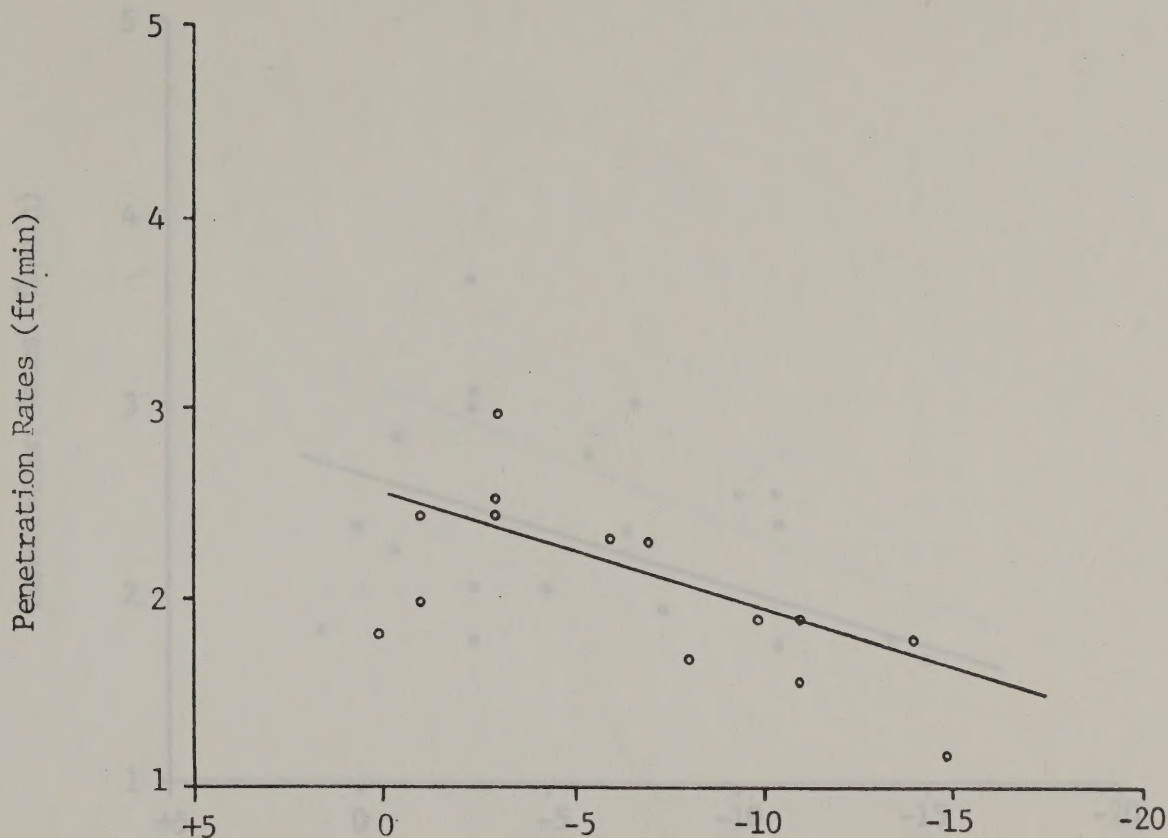
PERCUSSION HAMMER STROKE SETTING	CONVERSION TO 4" BIT TIME (Feet/Minute)	FEET PER MINUTE	TIME TO DRILL 12' (Minutes)	± HAMMER STROKE	BIT SIZE
750	3.61	3.61	3.32	-3	4"
-0-	2.91	2.91	4.12	-3	4"
1,500	3.08	3.08	3.90	-7	4"
1,000	2.82	2.82	4.20	-6	4"
750	2.68	2.68	4.47	-6	4"
-0-	2.29	2.29	5.23	-6	4"
1,500	2.71	2.71	4.42	-10	4"
1,000	2.38	2.38	5.02	-10	4"
750	2.20	2.20	4.80	-10	4"
-0-	1.82	1.82	6.20	-10	4"
1,500	1.20	1.20	8.00	-12	4"

Conversion factor to 4" bit penetration rates:
 3" to 4" x .620
 2 1/2" to 4" x .492
 2 1/4" to 4" x .442
 2" to 4" x .324

* Data are both penetration and rotary penetration type.

GARDNER-DENVER ALL HYDRAULIC ROTARY PERCUSSION DRILL TEST

Results with 0 psi percussion hammer stroke gauge setting, 4,000 blows per minute at 100 foot pounds per blow. All penetration rates are for 4" bits.

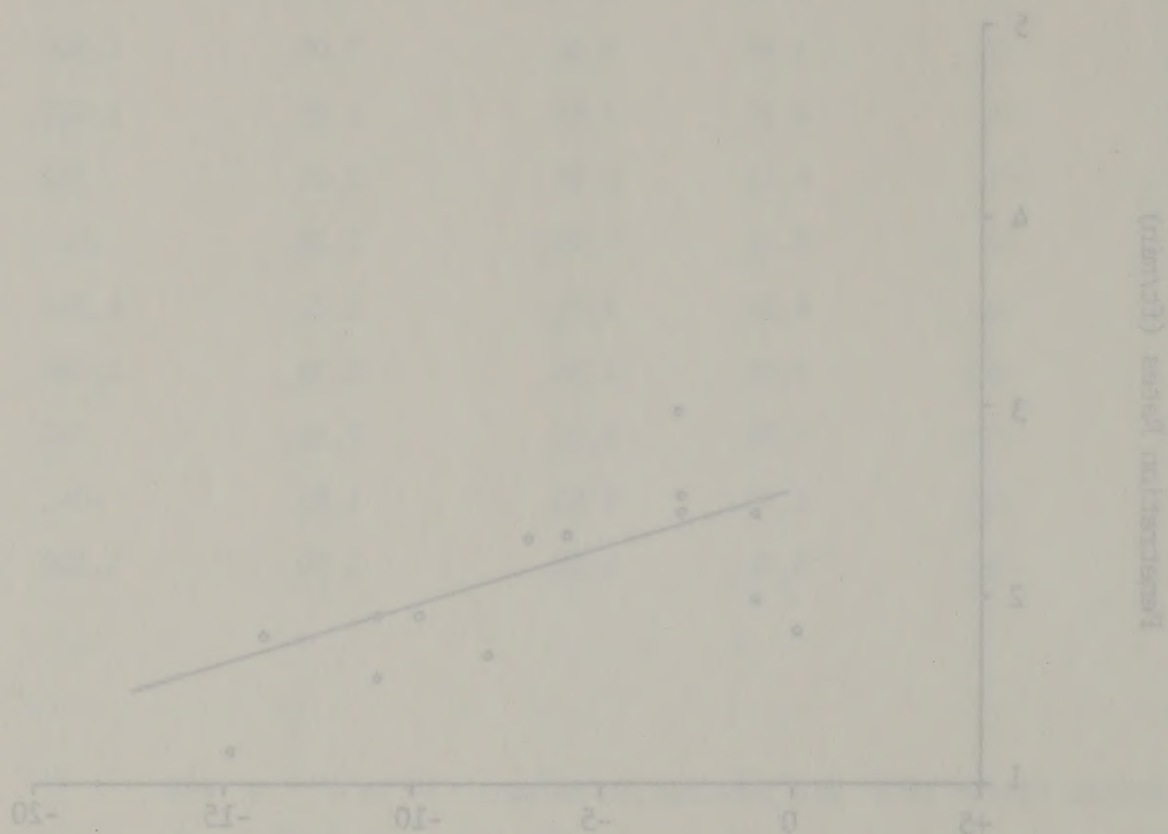


Face location with respect to Mahogany marker with approximate grade and compressive strength in the following Table:

Face Location (\pm Mm)	-1	-1	-3	-3	-7	-7	-11	-15
Grade (gal/ton)	9.9	9.9	11.1	11.1	46.3	46.3	21.4	86.6
Approximate Compressive Strength (lbs/sq in)	24,000	24,000	23,000	23,000	9,500	9,500	16,500	8,000

SWISS-DRIVER ALL METALLIC ROTARY PERCUSSION DRILL TEST

Handiles with 0 psi percutaneous hammer stroke setting, 8,000 blows per minute at 100 foot pounds per blow. All penetration rates are for 4" dia.

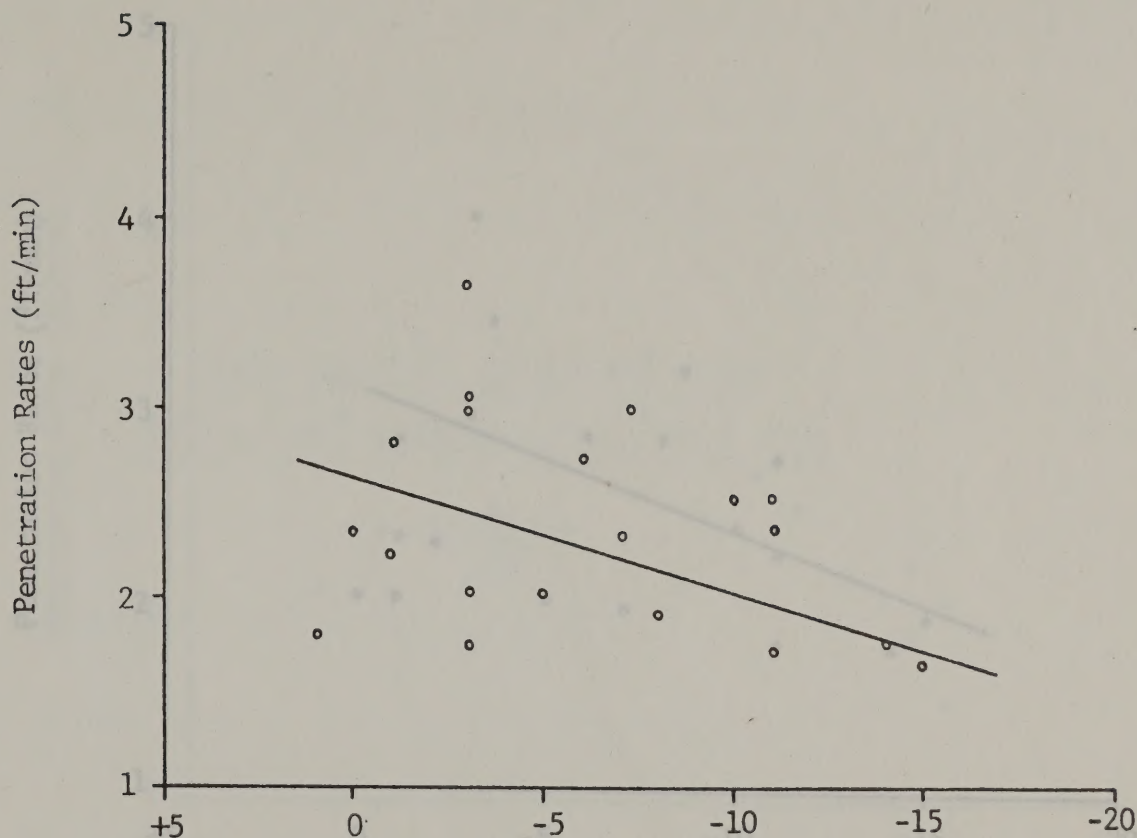


Face location with respect to Mahogany marker with approximate grade and compressive strength in the following Table:

Face location (ft)	Grade (gal/ton)	Approximate Compressive Strength (lb/sq ft)
-1	9.9	24,000
-3	11.1	23,000
-7	46.3	9,500
-11	21.4	16,500
-15	86.6	8,000

GARDNER-DENVER ALL HYDRAULIC ROTARY PERCUSSION DRILL TEST

Results with 750 psi percussion hammer stroke gauge setting, 3,500 blows per minute at 133 foot pounds per blow. All penetration rates are for 4" bits.

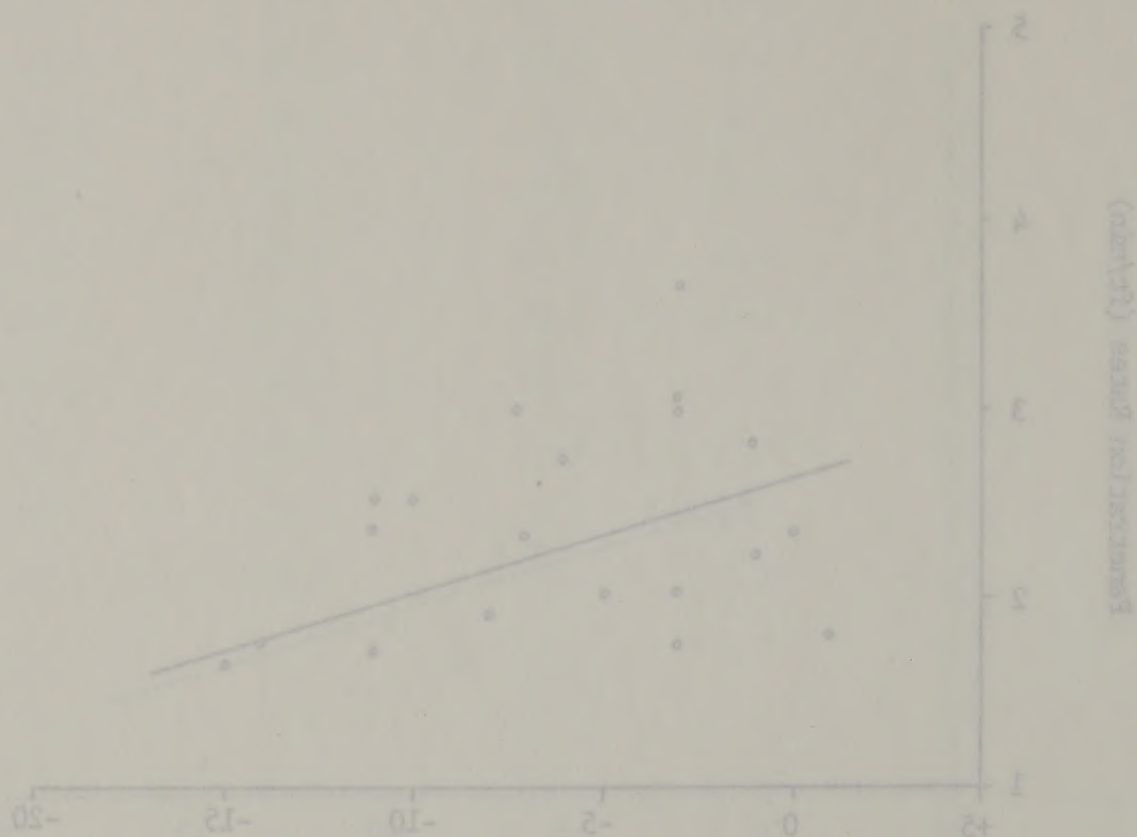


Face location with respect to Mahogany marker with approximate grade and compressive strength in the following Table:

Face Location (\pm Mm)	-1	-3	-7	-11	-15
Grade (gal/ton)	9.9	11.1	46.3	21.4	86.6
Approximate Compressive Strength (lbs/sq in)	24,000	23,000	9,500	16,500	8,000

CORRELATION BETWEEN ALL HYDRAULIC ROTARY PERCUSSION DRILL TEST

Results with 750 psi percussion hammer stroke gauge setting, 2,500 blows per minute at 133 foot pounds per blow. All penetration rates are for 4' bits.

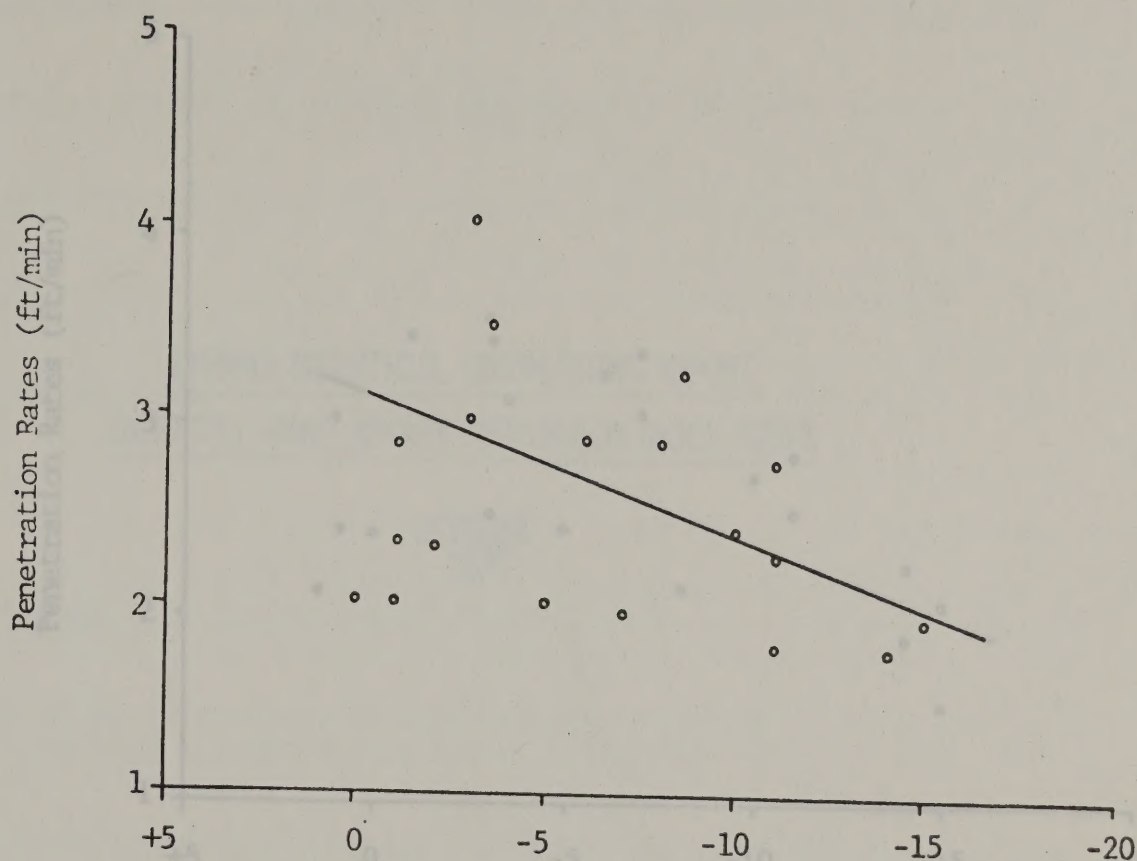


Face Location with respect to Mohr's circle with approximate grade and compressive strength in the following table:

Face Location (T.M.)	Grade (gal/cm)	Approximate Compressive Strength (lb/sq in)
-12	21.4	8,000
-11	21.4	16,500
-7	26.3	2,500
-3	11.1	27,000
-1	9.8	28,000

GARDNER-DENVER ALL HYDRAULIC ROTARY PERCUSSION DRILL TEST

Results with 1,000 psi percussion hammer stroke gauge setting, 3,000 blows per minute at 166 foot pounds per blow. All penetration rates are for 4" bits.

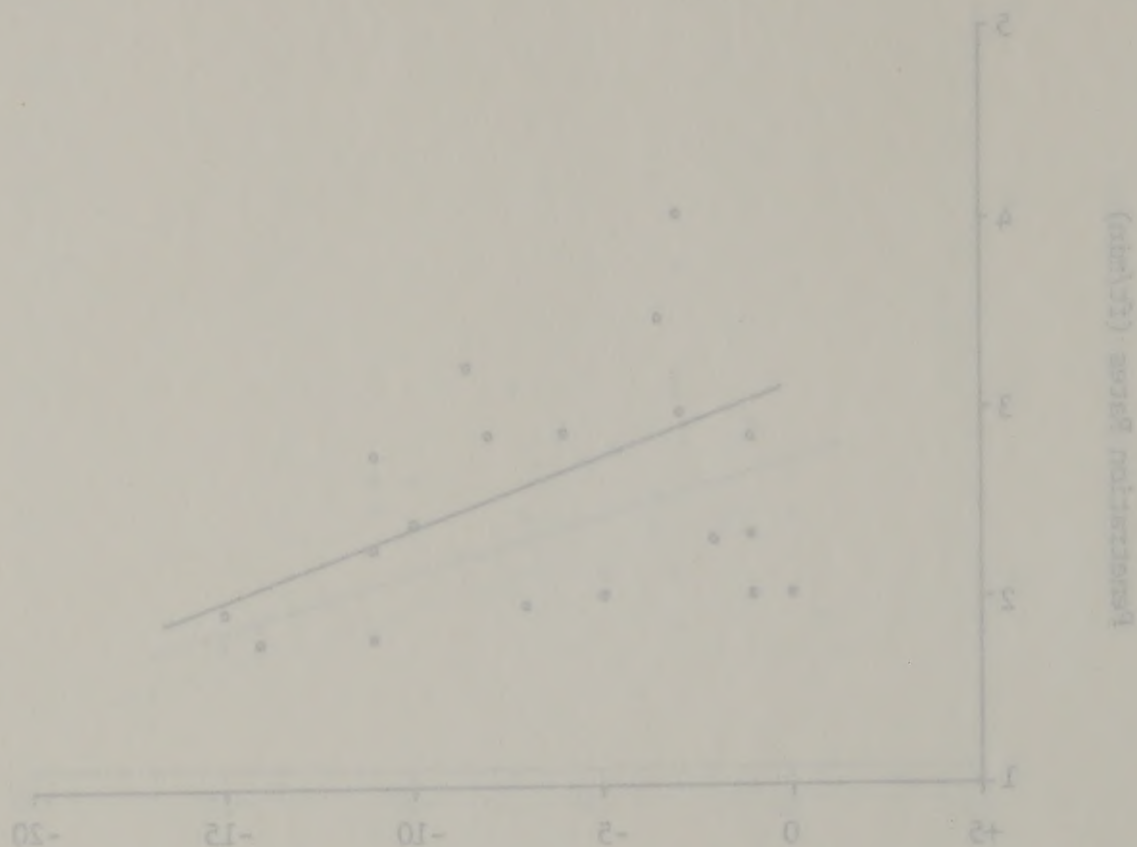


Face location with respect to Mahogany marker with approximate grade and compressive strength in the following Table:

Face Location (\pm Mn)	-1	-3	-7	-11	-15
Grade (gal/ton)	9.9	11.1	46.3	21.4	86.6
Approximate Compressive Strength (lbs/sq in)	24,000	23,000	9,500	16,500	8,000

GARDNER-DENVER AIR HYDRAULIC ROTARY PENETRATION DRILL TEST

Results with 1,000 psi penetration hammer stroke gauge setting, 1,000
blows per minute at 100 foot pounds per blow. All penetration rates
are for 4" bits.

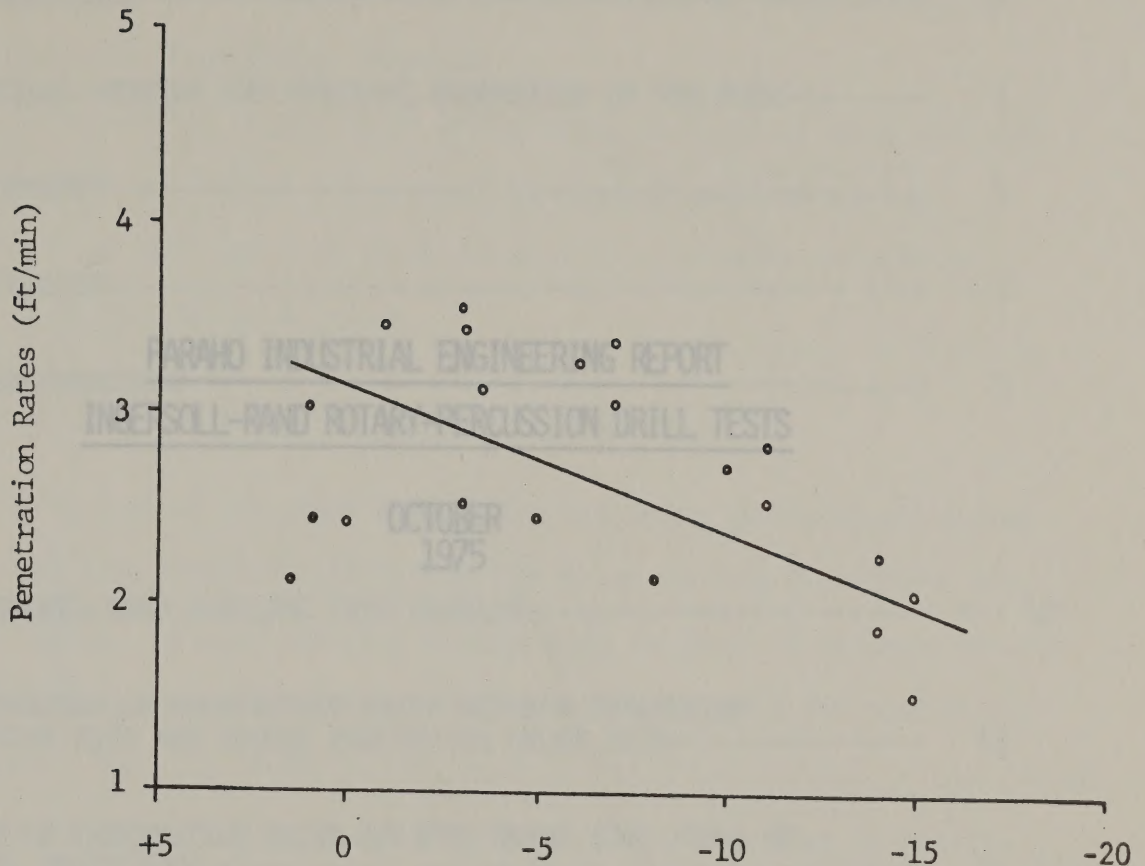


Face location with respect to Mahogany marker with
approximate grade and compressive strength in the
following table:

Face Location (ft)	Grade (gal/cm)	Approximate Compressive Strength (lb/sq in)
-1	9.9	24,000
-3	11.1	23,000
-7	46.3	9,500
-11	21.4	16,500
-15	86.6	8,000

GARDNER-DENVER ALL HYDRAULIC ROTARY PERCUSSION DRILL TEST

Results with 1,500 psi percussive hammer stroke gauge setting, 2,500 blows per minute at 200 foot pounds per blow. All penetration rates are for 4" bits.



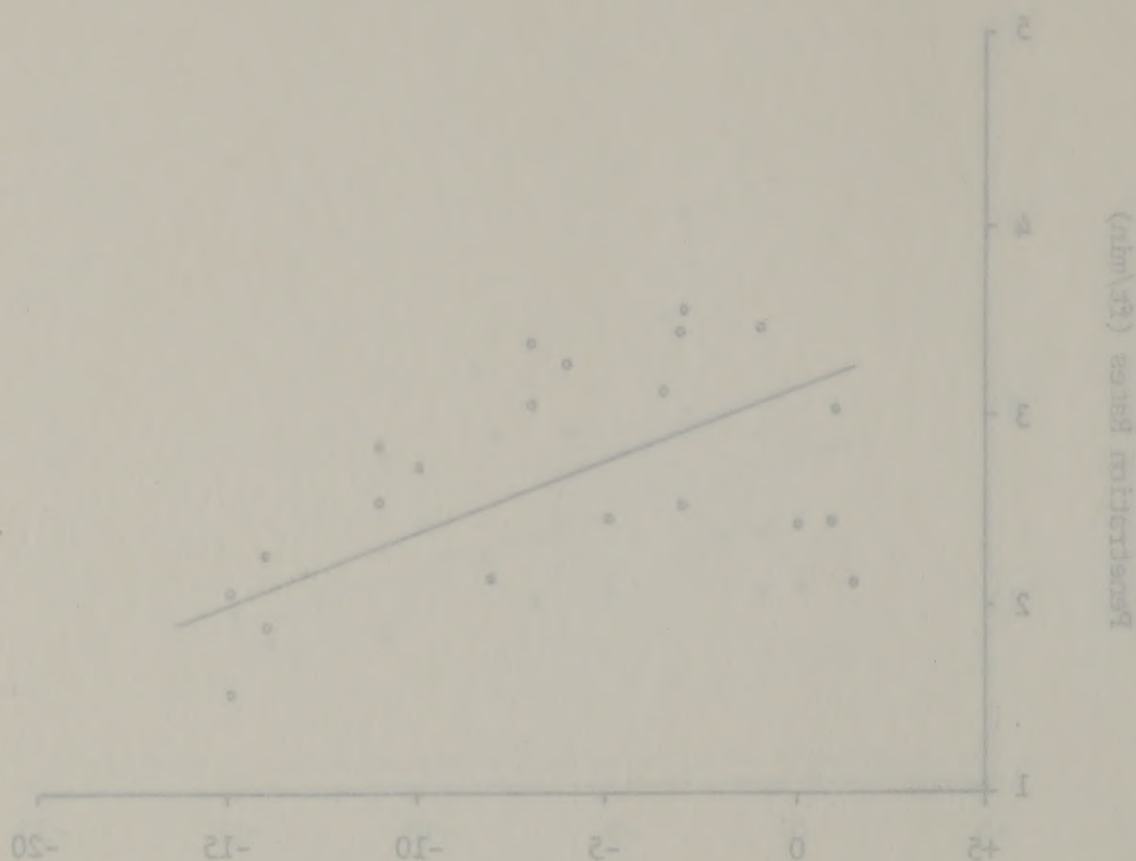
Face location with respect to Mahogany marker with approximate grade and compressive strength in the following Table:

Face Location (\pm Mn)	-1	-3	-7	-11	-15
Grade (gal/ton)	9.9	11.1	46.3	21.4	86.6
Approximate Compressive Strength (lbs/sq in)	24,000	23,000	9,500	16,500	8,000

WES MOUTON
GEOLOGICAL ENGINEER

CARNEGIE-DEWEY AIR HYDRAULIC ROTARY PERCUSSION DRILL TEST

Results with 1,500 psi percussion hammer stroke setting, 2,500 blows per minute at 200 foot pounds per blow. All penetration rates are for 4" bits.



Face location with respect to Mahogany marker with approximate grade and compressive strength in the following Table:

Face location (ft)	Grade (gal/ton)	Approximate Compressive Strength (lbs/sq in)
-1	9.9	24,000
-3	11.1	23,000
-7	46.3	9,500
-11	21.4	16,500
-15	86.6	8,000

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BY

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PARAHIO INDUSTRIAL ENGINEERING REPORT
INTERCOL-RAND ROTARY-PERCUSSION DRILL TESTS

OCTOBER
1975

BY

WES MALLIN
GEOLOGICAL ENGINEER

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INGERSOLL-RAND TEST

1. INTRODUCTION

This test was conducted at the Paraho Demonstration Project's Anvil Points mine near Rifle, Colorado.

The section of oil shale being mined consists of both rich and lean zones with an average oil content of about 30 gallons per ton. Drillability of rich and lean shale zones differs greatly as each has definite physical characteristics.

2. PHYSICAL SETTING AND PHYSICAL PROPERTIES OF THE ROCK

The bulk of the rich shale zones lie below the Mahogany Marker but the rich zone drilled in this test was seven to nine feet above the Mahogany Marker. The oil content in this rock is 33 to 38 gallons per ton with rock compressive strengths ranging from 10,000 to 12,000 pounds per square inch. The rich shale is weak rock having a low modulus of elasticity and a high Poisson's Ratio. Percussion energy of percussion or rotary-percussion drilling is apparently easily dissipated in this type of rock. This is why in the rich shale the penetration rate is lower for percussion or rotary-percussion drilling than for rotary drilling.

The lean shale zones predominately lie above and immediately below the Mahogany Marker. The lean shale is strong and has a high modulus of elasticity and a low Poisson's Ratio. The lean zones used in this test are near the Mahogany Marker. The oil content in these zones ranges

INTEGRAL-RAND TEST

1. INTRODUCTION

This test was conducted at the Kansas Reclamation Project's
Avali Pointe mine near Rifle, Colorado.
The section of oil shale being mined consists of both rich and
lean zones with an average oil content of about 30 gallons per ton.
Reliability of rich and lean shale zones differs greatly as each has
different physical characteristics.

2. PHYSICAL SETTING AND PHYSICAL PROPERTIES OF THE ROCK

The bulk of the rich shale zones lie below the Mahogany Marker
but the rich zone drilled in this test was seven to nine feet above the
Mahogany Marker. The oil content in this rock is 33 to 38 gallons per ton
with rock compressive strengths ranging from 10,000 to 12,000 pounds per
square inch. The rich shale is weak rock having a low modulus of elasticity
and a high Poisson's Ratio. Penetration energy of percussion or rotary-
penetration drilling is apparently easily dissipated in this type of rock.
This is why in the rich shale the penetration rate is lower for percussion
or rotary-penetration drilling than for rotary drilling.
The lean shale zones predominate the above and immediately
below the Mahogany Marker. The lean shale is strong and has a high modulus
of elasticity and a low Poisson's Ratio. The lean zones used in this test
are near the Mahogany Marker. The oil content in these zones ranges

from 8 to 24 gallons per ton with compressive strengths ranging from 15,000 to 20,000 pounds per square inch. Rotary-percussion drilling in lean shale zones seems to attain higher penetration rates than straight rotary or percussion drilling.

3. EQUIPMENT

Ingersoll-Rand Company furnished a 96 M.J.M. diesel powered jumbo carrier equipped with an electric powered hydraulic system to test a Hard III all hydraulic rotary-percussion drill. The electric motor used to power the hydraulic system is rated at 150 H.P. The drill develops 600,000 foot pounds of energy per minute. Input horsepower ratings used in the hammer, rotation and thrust are as follows:

1. HAMMER:	40.00 H.P.
2. ROTATION:	8.75 H.P.
3. THRUST:	<u>1.50 H.P.</u>
TOTAL	50.25 H.P.

This drill was tested on four different days with twenty-eight holes drilled. The holes are recorded under the date drilled in Table I. Table II compares penetration rates of percussion cross bits to penetration rates of ground percussion cross bits. One 1-7/8" bit was not ground as it was a rotary-percussion bit. The 3" bits were ground down to simulate a rotary-percussion bit. As can be seen in the table, an increase in penetration rates were attained with the ground percussion bit. Most penetration rates for the ground percussion bits doubled the penetration rates for the straight percussion bits. Only 3" and 1-7/8" bits are included in Table II.

from 5 to 24 gallons per ton with compressive strengths ranging from 15,000 to 20,000 pounds per square inch. Rotary-percussion drilling in these zones seems to attain higher penetration rates than straight rotary or percussion drilling.

3. EQUIPMENT

Hydraulic-Hand Company furnished a 95 M.H.P. diesel powered jackhammer equipped with an electric powered hydraulic system to test a Hand III all hydraulic rotary-percussion drill. The electric motor used to power the hydraulic system is rated at 150 H.P. The drill develops 600,000 foot pounds of energy per minute. Input horsepower ratings used in the hammer, rotation and thrust are as follows:

1. HAMMER:	40.00 H.P.
2. ROTATION:	8.75 H.P.
3. THRUST:	1.50 H.P.
TOTAL:	50.25 H.P.

This drill was tested on four different days with twenty-eight holes drilled. The holes are recorded under the date drilled in Table I. Table II compares penetration rates of percussion cross bits to penetration rates of ground percussion cross bits. One 1-7/8" bit was not ground as it was a rotary-percussion bit. The 3" bits were ground down to simulate a rotary-percussion bit. As can be seen in the table, an increase in penetration rates were attained with the ground percussion bit. Most penetration rates for the ground percussion bit doubled the penetration rates for the straight percussion bit. Only 3" and 1-7/8" bits are included in Table II.

Tables III and III-A are plots of penetration rates against grade (gallons per ton) of oil shale rock. All numbers on the plots are recorded penetration rates for a 3" bit or calculated rates from other size bits.

4. CONCLUSION

The Ingersoll-Rand Hard III rotary-percussion drill performed well in the lean shale zones but penetration rates in the rich shale zones were poor. Overall drill potential seems to be good but combined with inadequate bit design and poor bit supply, overall penetration rates do not meet those of conventional rotary drilling.

5. RECOMMENDATIONS

It is recommended that Ingersoll-Rand meet with The Cleveland-Cliffs Iron Company to discuss future potential for their rotary percussion unit.

Bit design and supply with respect to rotary-percussion type drills for drilling experiments in oil shale rock are far behind drill development. It is recommended that a major bit manufacturer be persuaded to enter these experiments with new bit designs and adequate supplies of bits.

Recommendations regarding the Ingersoll-Rand 96 M.J.M. jumbo's hydraulic system are to utilize the rigs two hydraulic pumps by separating the feed hydraulic's system from the drill hydraulic's system. This would increase the feed and drill pressures which, in turn, would hopefully increase penetration rates.

Tables III and III-A are plots of penetration rates against grade (gallons per ton) of oil shale rock. All numbers on the plots are recorded penetration rates for a 3" bit or calculated rates from other data.

4. CONCLUSION

The Ingersoll-Rand III rotary-percussion drill performed well in the lean shale zones but penetration rates in the rich shale zones were poor. Overall drill potential seems to be good but combined with inadequate bit design and poor bit supply, overall penetration rates do not meet those of conventional rotary drilling.

5. RECOMMENDATIONS

It is recommended that Ingersoll-Rand meet with The Cleveland-Cutler Iron Company to discuss future potential for their rotary percussion drill.

Bit design and supply with respect to rotary-percussion type drills for drilling experiments in oil shale rock are far behind drill development. It is recommended that a major bit manufacturer be persuaded to enter these experiments with new bit designs and adequate supplies of bits.

Recommendations regarding the Ingersoll-Rand 36 M.J.M. Junior's hydraulic system are to utilize the rig's two hydraulic pumps by separating the feed hydraulic's system from the drill hydraulic's system. This would increase the feed and drill pressures which, in turn, would hopefully increase penetration rates.

TABLE I

Ingersoll-Rand Drilling Test Results

8-21-75

#1 ± Mahogany Marker +2.5 feet

Bit - 3" Percussion Cross Bit

Collar - Not available

Drill - 7 feet in 3.84 minutes = 1.82 feet/minute

Retract - Not available

#2 ± Mahogany Marker +1.0 foot

Bit - 3" Percussion Cross Bit (same bit as above)

Collar - Not available

Drill - 10 feet in 2.48 minutes = 4.03 feet/minute

Blew hydraulic pump seals

9-2-75

ALL HOLES DRILLED WITH A 4" PERCUSSION CROSS BIT

#1 ± Mahogany Marker +1.0 foot

Collar- .08 minutes

Drill - 10 feet in 5.09 minutes = 1.96 feet/minute

Retract - .32 minutes

Pressures - PSI:

Feed - 1250

Drill - 3150

Rotary - Not available

TABLE I

Ingersoll-Rand Drilling Test Results

8-21-75

41 = Mahogany Marker +1.5 feet

Bit - 3" Percussion Cross Bit

Collar - Not available

Drill - 7 feet in 3.84 minutes = 1.82 feet/minute

Reactor - Not available

42 = Mahogany Marker +1.0 foot

Bit - 3" Percussion Cross Bit (same bit as above)

Collar - Not available

Drill - 10 feet in 3.48 minutes = 4.03 feet/minute

Blow hydraulic pump seals

9-2-75

ALL HOLES DRILLED WITH A 4" PERCUSSION CROSS BIT

41 = Mahogany Marker +1.0 foot

Collar - .08 minutes

Drill - 10 feet in 5.09 minutes = 1.96 feet/minute

Reactor - .35 minutes

Pressure - PSI:

Feed - 1250

Drill - 3150

Rotary - Not available

#2 ± Mahogany Marker -1'2"

Collar - .10 minutes

Drill - 10 feet in 7.04 minutes = 1.42 feet/minute

Retract - Not available

Pressures - PSI:

Feed - 1250

Drill - 3150

Rotary - Not available

#3 ± Mahogany Marker - 2'4"

Collar - .09 minutes

Drill - 10 feet in 6.65 minutes = 1.50 feet/minute

Retract - .35 minutes

Pressures - PSI:

Feed - 1250

Drill - 3150

Rotary - Not available

#4 ± Mahogany Marker + 5'7"

Collar - .07 minutes

Drill - 10 feet in 9.38 minutes = 1.07 feet/minute

Retract - .36 minutes

Pressures - PSI:

Feed - 1600

Drill - 3150

Rotary - Not available

43 : Mercury Marker - 1'7"

Collar - .10 minutes

Drill - 10 feet in 7.04 minutes = 1.42 feet/minute

Retract - Not available

Pressures - PSI:

Feed - 1250

Drill - 3150

Rotary - Not available

43 : Mercury Marker - 2'4"

Collar - .09 minutes

Drill - 10 feet in 6.63 minutes = 1.50 feet/minute

Retract - .35 minutes

Pressures - PSI:

Feed - 1250

Drill - 3150

Rotary - Not available

44 : Mercury Marker + 2'7"

Collar - .07 minutes

Drill - 10 feet in 9.38 minutes = 1.07 feet/minute

Retract - .36 minutes

Pressures - PSI:

Feed - 1600

Drill - 3150

Rotary - Not available

#5 ± Mahogany Marker + 10'2"

Collar - .22 minutes

Drill - 10 feet in 8.19 minutes = 1.22 feet/minute

Retract - Not available

Pressures - PSI:

Feed - 1500

Drill - 2900

Rotary - Not available

9-3-75

#1 ± Mahogany Marker -1'2"

Collar - .10 minutes

Drill - 10 feet in 4.69 minutes = 2.13 feet/minute

Retract - .31 minutes

Pressures - PSI:

Feed - 1700

Drill - 3050

Rotary - Not available

Bit - 2 1/2" Percussion Cross Bit

#2 ± Mahogany Marker - 3'2"

Collar - .09 minutes

Drill - 10 feet in 5.90 minutes = 1.69 feet/minute

Retract - Not available

Pressures - PSI:

Feed - 1400

Drill - 3050

Rotary - Not available

Bit - 2 1/2" Percussion Cross Bit

42 * Mahogany Marker + 10'2"

Collar - . 22 minutes

Drill - 10 feet in 8.19 minutes = 1.22 feet/minute

Retract - Not available

Pressure - PSI:

Feed - 1200

Drill - 3200

Rotary - Not available

9-3-75

41 * Mahogany Marker - 1'2"

Collar - . 10 minutes

Drill - 10 feet in 4.69 minutes = 2.13 feet/minute

Retract - . 31 minutes

Pressure - PSI:

Feed - 1200

Drill - 3050

Rotary - Not available

Bit - 2 1/2" Perconator Gross Bit

43 * Mahogany Marker - 3'2"

Collar - . 09 minutes

Drill - 10 feet in 2.90 minutes = 1.69 feet/minute

Retract - Not available

Pressure - PSI:

Feed - 1200

Drill - 3050

Rotary - Not available

Bit - 2 1/2" Perconator Gross Bit

#3 ± Mahogany Marker - 1.0 foot

Collar - .12 minutes

Drill - 10 feet in 3.07 minutes = 3.25 feet/minute

Retract - Not available

Pressures - PSI:

Feed - 1450

Drill - 3050

Rotary - Not available

Bit - 3" Button Bit Cross Bit

#4 ± Mahogany Marker - 4'3"

Collar - .10 minutes

Drill - 10 feet in 4.35 minutes = 2.29 feet/minute

Retract - Not available

Pressures - PSI:

Feed - 1450

Drill - 2950

Rotary - Not available

Bit - 3" Button Bit Cross Bit

#5 ± Mahogany Marker - 2'3"

Collar - 10 minutes

Drill - 10 feet in 4.36 minutes = 2.29 feet/minute

Retract - 36 minutes

Pressures - PSI:

Feed - 1450

Drill - 3150

Rotary - Not available

Bit - 3" Button Bit

43 : Magnetogly Meter - 1.0 foot

Collar - .15 minutes

Drill - 10 feet in 3.07 minutes = 3.25 feet/minute

Retract - Not available

Pressure - PSI:

Feed - 1450

Drill - 3050

Rotary - Not available

Bit - 3" Button Bit

44 : Magnetogly Meter - 4.7"

Collar - .10 minutes

Drill - 10 feet in 4.35 minutes = 2.29 feet/minute

Retract - Not available

Pressure - PSI:

Feed - 1450

Drill - 3950

Rotary - Not available

Bit - 3" Button Bit

45 : Magnetogly Meter - 2.7"

Collar - .10 minutes

Drill - 10 feet in 4.36 minutes = 2.29 feet/minute

Retract - .36 minutes

Pressure - PSI:

Feed - 1450

Drill - 3150

Rotary - Not available

Bit - 3" Button Bit

#6 ± Mahogany Marker - 8"

Oil Content - 14.6 Gal/Ton

Collar - .07 minutes

Drill - 10 feet in 4.75 minutes = 2.10 feet/minute

Retract - .38 minutes

Pressures - PSI:

Feed - 1400

Drill - 3000

Rotary - Not available

Bit - 3" Percussion Cross Bit

#7 ± Mahogany Marker +4'

Oil Content - 18.2 Gal/Ton

Collar - .09 minutes

Drill - 10 feet in 5.77 minutes = 1.73 feet/minute

Retract - Not available

Pressures - PSI:

Feed - 1450

Drill - 3000

Rotary - Not available

Bit - 3" Percussion Cross Bit

9-16-75

#1 ± Mahogany Marker -9"

Oil Content - 10.9 Gal/Ton

Collar - Not available

Drill - 10 feet in 2.09 minutes = 4.78 feet/minute

Retract - Not available

Pressures - PSI:

Feed - 1450

Drill - 1450

Rotary - 3000

Bit - 3" Ground Percussion Bit

46 : Hydrogen Meter - 8"

Collar - 07 minutes

Drill - 10 feet in 4.75 minutes = 2.10 feet/minute

Retract - 38 minutes

Pressures - PSI:

Feed - 1400

Drill - 3000

Rotary - Not available

Bit - 3" Perseus Cross Bit

47 : Hydrogen Meter - 4"

Collar - 09 minutes

Drill - 10 feet in 5.77 minutes = 1.73 feet/minute

Retract - Not available

Pressures - PSI:

Feed - 1450

Drill - 3000

Rotary - Not available

Bit - 3" Perseus Cross Bit

9-16-75

Oil Content - 10.9 Gal/Ton

48 : Hydrogen Meter - 9"

Collar - Not available

Drill - 10 feet in 3.09 minutes = 4.78 feet/minute

Retract - Not available

Pressures - PSI:

Feed - 1450

Drill - 1450

Rotary - 3000

Bit - 3" Ground Perseus Bit

#2 ± Mahogany Marker +10'

Oil Content - 14.6 Gal/Ton

Collar - .11 minutes

Drill - 10 feet in 2.48 minutes = 4.03 feet/minute

Retract - .33 minutes

Pressures - PSI:

Feed - 1350

Drill - 1450

Rotary - 2950

Bit - 3" Ground Percussion Bit

#3 ± Mahogany Marker +2'

Oil Content - 18.2 Gal/Ton

Collar - .12 minutes

Drill - 10 feet in 2.52 minutes = 3.96 feet/minute

Retract - .36 minutes

Pressures - PSI:

Feed - 1350

Drill - 1400

Rotary - 2800

Bit - 3" Ground Percussion Cross Bit

#4 ± Mahogany Marker +7'2"

Oil Content - 33.1 Gal/Ton

#4 ± Mahogany Marker -9"

Oil Content - 8.0 Gal/Ton

Collar - Not available

Drill - 10 feet in 3.42 minutes = 2.92 feet/minute

Retract - .35 minutes

Pressures - PSI:

Feed - 1250

Drill - 1500

Rotary - 2750

Bit - 4" Ground Percussion Cross Bit

Oil Content - 14.6 Gal/Ton

42 - Mahogany Marker - 10'

Collar - .11 minutes

Drill - 10 feet in 2.48 minutes = 4.03 feet/minute

Retract - .33 minutes

Pressures - PSI:

Feed - 1350

Drill - 1450

Rotary - 2950

Bit - 3" Ground Permutation Bit

Oil Content - 18.2 Gal/Ton

43 - Mahogany Marker - 12'

Collar - .12 minutes

Drill - 10 feet in 2.52 minutes = 3.96 feet/minute

Retract - .36 minutes

Pressures - PSI:

Feed - 1350

Drill - 1400

Rotary - 2800

Bit - 3" Ground Permutation Cross Bit

Oil Content - 8.0 Gal/Ton

44 - Mahogany Marker - 9"

Collar - Not available

Drill - 10 feet in 3.42 minutes = 2.92 feet/minute

Retract - .35 minutes

Pressures - PSI:

Feed - 1250

Drill - 1500

Rotary - 2750

Bit - 4" Ground Permutation Cross Bit

#5 ± Mahogany Marker +7'4"

Oil Content - 38.4 Gal/Ton

Collar - Not available

Drill - 10 feet in 9.03 minutes = 1.10 feet/minute

Retract - .39 minutes

Pressures - PSI:

Feed - 1250

Drill - 1500

Rotary - 2650

Bit - 4" Ground Percussion Cross Bit

#6 ± Mahogany Marker +7'

Collar - .08 minutes

Drill - 10 feet in 4.21 minutes = 2.37 feet/minute

Retract - .31 minutes

Pressures - PSI:

Feed - 1350

Drill - 1300

Rotary - 2700

Bit - 3" Ground Percussion Cross Bit

#7 ± Mahogany Marker +7'2"

Oil Content - 33.1 Gal/Ton

Collar - .11 minutes

Drill - 10 feet in 3.41 minutes = 2.93 feet/minute

Retract - .31 minutes

Pressures - PSI:

Feed - 1600

Drill - 1550

Rotary - 3150

Bit - 3" Ground Percussion Cross Bit

Oil Content - 38.4 Gal/Ton

45 - Nitrogen Marker +7.6"

Collar - Not available

Drill - 10 feet in 9.03 minutes = 1.10 feet/minute

Retract - .39 minutes

Pressure - PSI

Feed - 1350

Drill - 1500

Rotary - 3850

Bit - 4" Ground Penetration Cross Bit

46 - Nitrogen Marker +7.1"

Collar - .08 minutes

Drill - 10 feet in 4.21 minutes = 2.37 feet/minute

Retract - .31 minutes

Pressure - PSI

Feed - 1350

Drill - 1300

Rotary - 3700

Bit - 3" Ground Penetration Cross Bit

Oil Content - 33.1 Gal/Ton

47 - Nitrogen Marker +7.2"

Collar - .11 minutes

Drill - 10 feet in 3.41 minutes = 2.93 feet/minute

Retract - .31 minutes

Pressure - PSI

Feed - 1600

Drill - 1550

Rotary - 3150

Bit - 3" Ground Penetration Cross Bit

#8 ± Mahogany Marker +10'

Oil Content - 21.4 Gal/Ton

Collar - .10 minutes

Drill - 10 feet in 2.82 minutes = 3.54 feet/minute

Retract - .37 minutes

Pressures - PSI:

Feed - 1750

Drill - 1800

Rotary - 3200

Bit - 3" Ground Percussion Cross Bit

9 and 10

4" Button Bit - bit would collar the hole but no penetration was attained. Bit was tried in both lean and rich shale zones.

#11 ± Mahogany Marker +8'

Collar - .07 minutes

Drill - 10 feet in 4.45 minutes = 2.24 feet/minute

Retract - Not available

Pressures - PSI:

Feed - 1250

Drill - 1600

Rotary - 3150

Bit - 1 7/8" -X-Bit - Bit plugged.

#12 ± Mahogany Marker +7'6"

Oil Content - 24.4 Gal/Ton

Collar - .08 minutes

Drill - 10 feet in 4.23 minutes = 2.36 feet/minute

Retract - Not available

Oil Content - 21.4 Gal/Ton

48 : Mahogany Marker +10'

Collar - .10 minutes

Drill - 10 feet in 2.82 minutes = 3.54 feet/minute

Retract - .37 minutes

Pressure - PSI:

Feed - 1750

Drill - 1800

Rotary - 3200

Bit - 7" Girard Perceussion Cross Bit

9 and 10

4" Bottom Bit - bit would collar the hole but no penetration was

achieved. Bit was tried in both lean and rich shale zones.

411 : Mahogany Marker +8'

Collar - .07 minutes

Drill - 10 feet in 4.45 minutes = 2.24 feet/minute

Retract - Not available

Pressure - PSI:

Feed - 1250

Drill - 1600

Rotary - 3150

Bit - 1 7/8" - X-Bit - Bit plugged.

Oil Content - 24.4 Gal/Ton

412 : Mahogany Marker +7'6"

Collar - .08 minutes

Drill - 10 feet in 4.23 minutes = 2.36 feet/minute

Retract - Not available

Pressures - PSI:

Feed - 1250

Drill - 1500

Rotary - 2950

Bit - 1 7/8" -X-Bit - Bit plugged.

#13 ± Mahogany Marker +7'5"

Oil Content - 38.0 Gal/Ton

Collar - .10 minutes

Drill - 10 feet in 2.35 minutes = 4.25 feet/minute

Retract - Not available

Pressures - PSI:

Feed - 1250

Drill - 1500

Rotary - 3150

Bit - 1 7/8" Rotary Percussion Bit

#14 ± Mahogany Marker -8"

Oil Content - 22 Gal/Ton

Collar - .11 minutes

Drill - 10 feet in 1.60 minutes = 6.25 feet/minute

Retract - Not available

Pressures - PSI:

Feed - 1250

Drill - 1500

Rotary - 3150

Bit - 1 7/8" Rotary Percussion Bit

Pressure - PSI:
 Feed - 1250
 Drill - 1500
 Rotary - 2950
 Bit - 1 7/8" - X-Bit - Bit plugged.
 Oil Content - 38.0 Gal/Ton
 Collar - 10 minutes
 Drill - 10 feet in 2.35 minutes = 4.25 feet/minute
 Retract - Not available
 Pressure - PSI:
 Feed - 1250
 Drill - 1500
 Rotary - 3150
 Bit - 1 7/8" Rotary Percussion Bit
 Oil Content - 22 Gal/Ton
 Collar - 11 minutes
 Drill - 10 feet in 1.60 minutes = 6.25 feet/minute
 Retract - Not available
 Pressure - PSI:
 Feed - 1250
 Drill - 1500
 Rotary - 3150
 Bit - 1 7/8" Rotary Percussion Bit

TABLE IIComparison of Penetration RatesBetween Percussion Cross Bits and Ground Percussion Cross Bits

<u>Bit</u>	<u>± Mahogany Marker</u>	<u>Penetration Feet/Minute</u>	<u>Gallons/Ton</u>
3" Percussion Cross Bit	+4' 0"	1.73	Not available
3" Percussion Cross Bit	+2' 5"	1.82	Not available
3" <u>Ground</u> Percussion Cross Bit	+2' 0"	3.96	18.2
3" Percussion Cross Bit	+1' 0"	4.03	Not available
3" <u>Ground</u> Percussion Cross Bit	-9"	4.78	10.9
3" <u>Ground</u> Percussion Cross Bit	+7'	2.37	Not available
3" <u>Ground</u> Percussion Cross Bit	+7' 2"	2.93	33.1
3" <u>Ground</u> Percussion Cross Bit	+10' 2"	3.54	21.4
3" Percussion Cross Bit	-8"	2.10	Not available
1-7/8" Percussion Cross Bit	+7' 6"	2.36	24.4
1-7/8" Percussion Cross Bit	+8' 0"	2.24	Not available
1-7/8" Rotary Percussion Bit	+7' 5"	4.25	38.0
1-7/8" Rotary Percussion Bit	-8"	6.25	22.3

TABLE II

Comparison of Penetration Rates

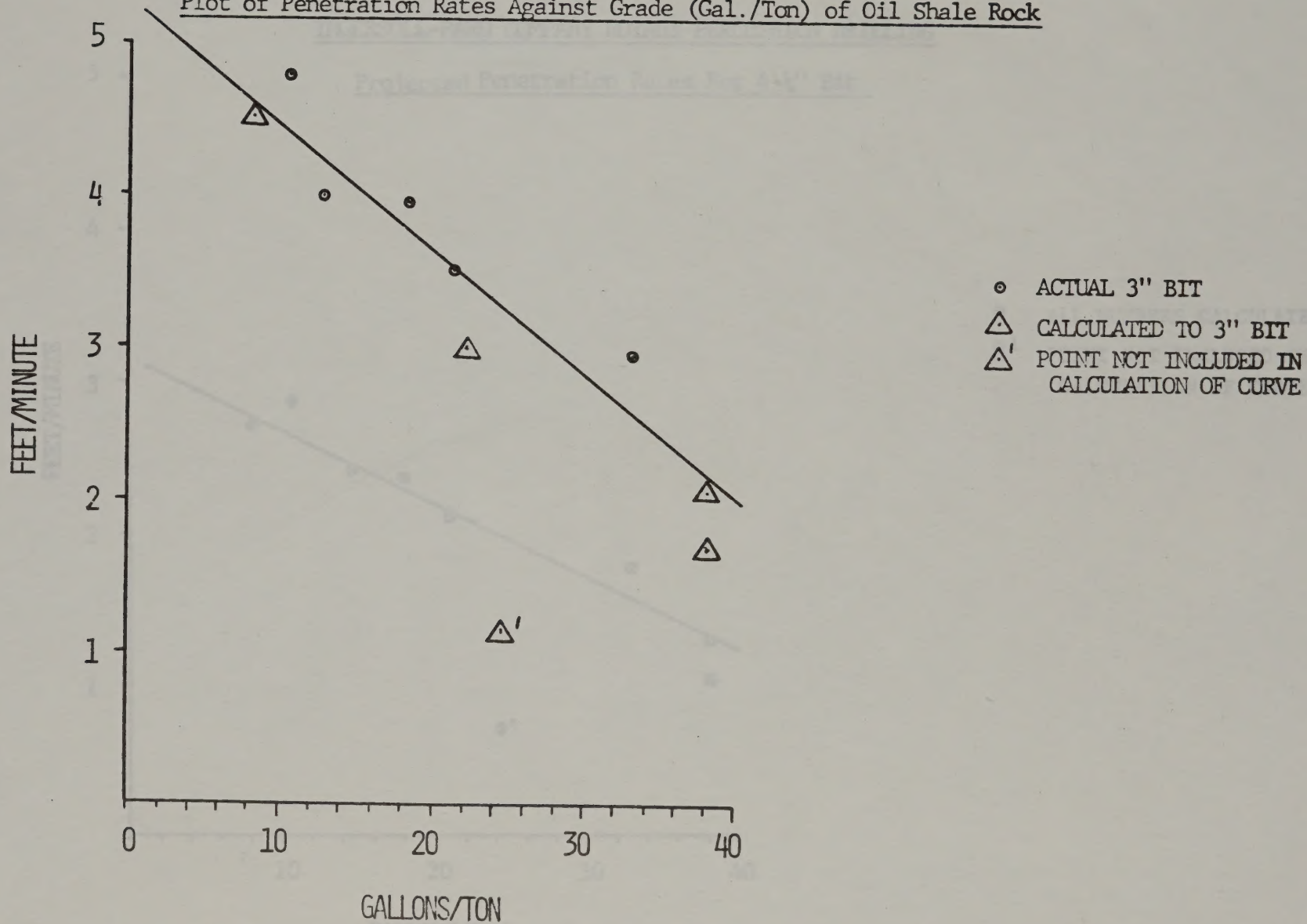
Between Penetration Cross Bits and Grand Penetration Cross Bits

Penetration Feet/Minute	Penetration Gallons/Ton	Rotary Penetration Bit	Grand Penetration Cross Bit	Penetration Feet/Minute	Penetration Gallons/Ton
1.73	Not available	+4' 0"	3" Penetration Cross Bit	1.82	Not available
1.82	Not available	+4' 2"	3" Penetration Cross Bit	2.96	18.2
2.96	18.2	+4' 0"	3" Grand Penetration Cross Bit	4.03	Not available
4.03	Not available	+4' 0"	3" Penetration Cross Bit	4.78	10.9
4.78	10.9	-9"	3" Grand Penetration Cross Bit	5.27	Not available
5.27	Not available	+7'	3" Grand Penetration Cross Bit	5.93	33.1
5.93	33.1	+7' 2"	3" Grand Penetration Cross Bit	6.25	21.4
6.25	21.4	+10' 2"	3" Grand Penetration Cross Bit	2.10	Not available
2.10	Not available	-8"	3" Penetration Cross Bit	2.36	24.4
2.36	24.4	+7' 6"	1-7/8" Penetration Cross Bit	2.24	Not available
2.24	Not available	+8' 0"	1-7/8" Penetration Cross Bit	4.25	38.0
4.25	38.0	+7' 2"	1-7/8" Rotary Penetration Bit	6.25	22.3
6.25	22.3	-8"	1-7/8" Rotary Penetration Bit		

TABLE III

INGERSOLL-RAND COMPANY ROTARY PERCUSSION DRILLING

Plot of Penetration Rates Against Grade (Gal./Ton) of Oil Shale Rock



ENTRANCE

0 10 20 30 40

1

2

3

4

5

FEET/MINUTE

-41-

ENTRANCE OF CREEK
 TOTAL WAS LIMITED IN
 CATCHED TO 3.0 HIL
 VOLUME 3.0 HIL

△, △
 •

Plot of Entrance Area versus Creek (Cm) of 0.1 HIL HOK

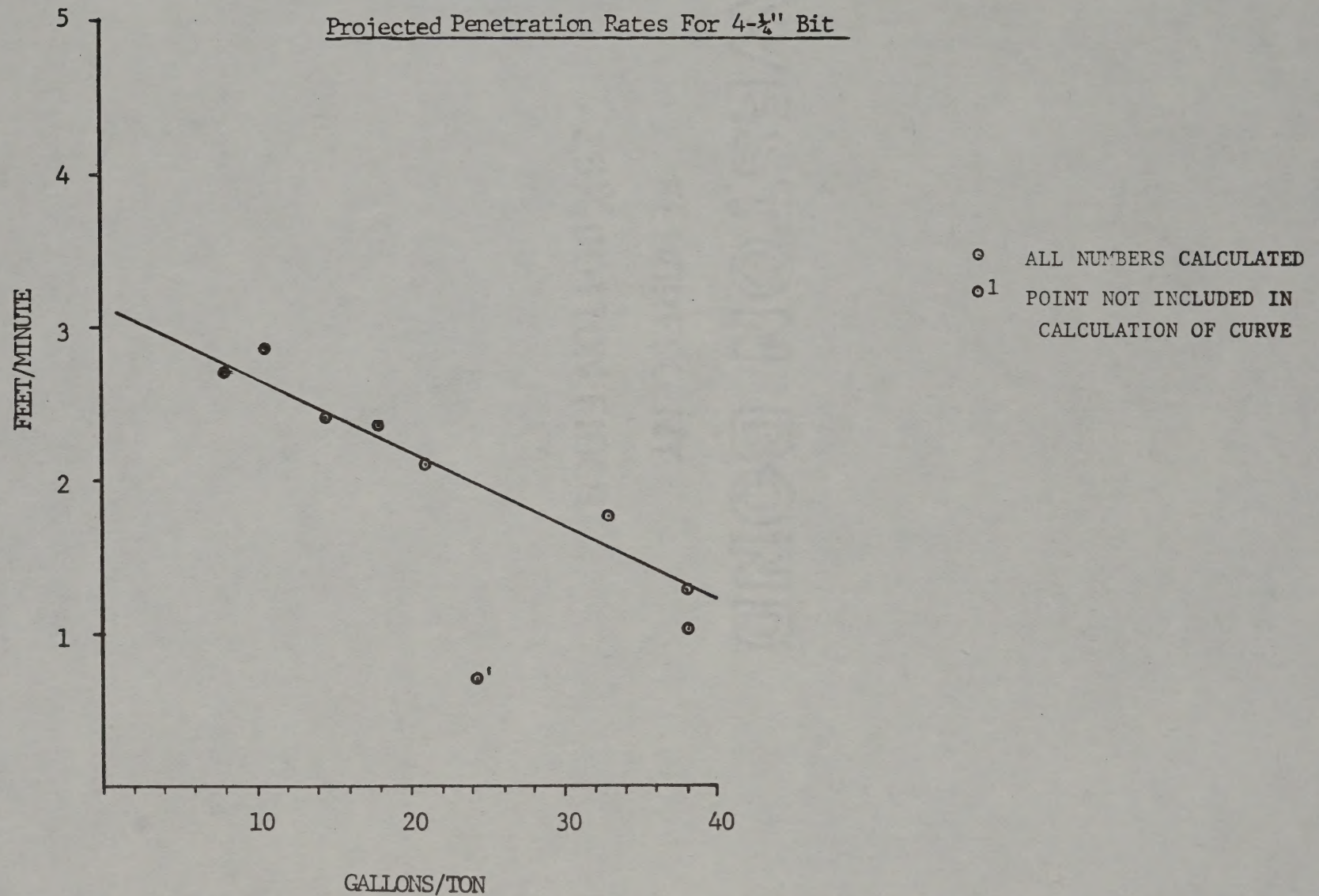
DESIGN-AND CREEK AREA REGRESSION METHOD

DATE III

TABLE III-A

INGERSOLL-RAND COMPANY ROTARY PERCUSSION DRILLING

Projected Penetration Rates For 4- $\frac{1}{2}$ " Bit



WESTON BOND

RECEIVED

EXHIBITION

1910

JOY DRILL AND BIT TEST

INTRODUCTION

On December 8, 1975, a Joy Mustang track drill, equipped with a Joy V.C.R. valvelless, rotary percussive drill, was tested at the Paraho Demonstration Project's Anvil Pointe Mine near Rifle, Colorado. The Joy Mustang track drill, including all the equipment and freight charges, was furnished at no expense by Ferris Equipment Company of Denver, Colorado.

PARAHO DEMONSTRATION PROJECT

JOY DRILL AND BIT TEST

DECEMBER, 1975

EQUIPMENT

The V.C.R.-280 is a valvelless continuous rotation drill which consumes 1,200 cubic feet of air per minute at an air pressure of 100 pounds per square inch. The hammer operates (percussive) at 2,000 blows per minute with 300 foot pounds per blow. Rotation speed is variable with a maximum rotation of 300 revolutions per minute.

Air to operate the drill is supplied by a Joy RPS-1300 diesel-powered air compressor. This compressor is towed in back of the drill.

BY

W. W. MOULTON
GEOLOGICAL ENGINEER

EXPAND INVESTIGATION PROJECT
JOY DRILL AND PIT TEST
DECEMBER 1972

BY
N. W. KALTON
GEOLOGICAL ENGINEER

TEST RESULTS:

JOY DRILL AND BIT TEST

INTRODUCTION:

On December 8, 1975, a Joy Mustang track drill, equipped with a Joy V.C.R. valveless, rotary percussion drill, was tested at the Paraho Demonstration Project's Anvil Points Mine near Rifle, Colorado. The Joy Mustang track drill, including all the equipment and freight charges, was furnished at no expense by Farris Equipment Company of Denver, Colorado.

Vertical holes were drilled in the floor with the hole collar located approximately 20 feet below the Mahogany Marker. These holes were drilled in medium and high grade shale.

EQUIPMENT:

The V.C.R.-280 is a valveless continuous rotation drill which consumes 1,200 cubic feet of air per minute at an air pressure of 100 pounds per square inch. The hammer operates (percussion) at 2,000 blows per minute with 386 foot pounds per blow. Rotation speed is variable with a maximum rotation of 300 revolutions per minute.

Air to operate the drill is supplied by a Joy RPS-1300 diesel-powered air compressor. This compressor is towed in back of the drill.

JOY DRILL AND BIT TEST

INTRODUCTION

On December 8, 1915, a Joy Mining track drill, equipped with a Joy V.C.R. valveless, rotary percussion drill, was tested at the Paria Reclamation Project's Arrow Point Mine near Rifle, Colorado. The Joy Mining track drill, including all the equipment and freight charges, was furnished at no expense by Paria Reclamation Company of Denver, Colorado.

Vertical holes were drilled in the floor with the hole collar located approximately 30 feet below the highway marker. These holes were drilled in section and high grade shafts.

EQUIPMENT

The V.C.R.-180 is a valveless continuous rotation drill which consumes 1,200 cubic feet of air per minute at an air pressure of 100 pounds per square inch. The rotary operator (percussion) at 2,000 blows per minute with 388 foot pounds per blow. Rotation speed is variable with a maximum rotation of 300 revolutions per minute.

Air to operate the drill is supplied by a Joy W-1200 diesel-powered air compressor. This compressor is towed in back of the drill.

TEST RESULTS:

PROJECT: JOY DRILLING TEST

Two types of bits were tested. A 4" button bit was tested with poor results. Drilling rates averaged 2.2 feet per minute. The second bit tested was a percussion cross bit resharpened to simulate a rotary percussion bit. Twenty holes were drilled with this bit attaining an average penetration rate of 4.6675 feet per minute. (See Figure #1).

The average penetration rate combined with a potentially long bit life (one bit drilled 20 holes (360 feet) at 4.6675 feet/minute) makes this Joy drill and bit combination competitive with other drills investigated for use in future oil shale mining operations. One drawback noted during the drilling test was the amount of noise produced during the drilling cycle.

Table I is a detailed summary of the time taken to drill each hole. The holes are listed in the order they were drilled.

The operator performing the test was a demonstration operator employed by Joy.

Future study on the application of this type of drilling (rotary-percussion) to oil shale operations should be undertaken.

COST ESTIMATES:

An estimate of operating labor and supplies and maintenance labor and supplies is attached.

TEST RESULTS:

The types of bits were tested. A 4" button bit was tested with poor results. Drilling rates averaged 1.3 feet per minute. The second bit tested was a penetration cross bit resharpened to simulate a rotary penetration bit. Twenty holes were drilled with this bit attaining an average penetration rate of 4.6675 feet per minute. (See Figure #1).

The average penetration rate combined with a potentially long bit life (one bit drilled 20 holes (360 feet) at 4.6675 feet/minute) makes this a very efficient and bit combination competitive with other drills investigated for use in future oil shale mining operations. One drawback noted during the drilling test was the amount of noise produced during the drilling cycle.

Table I is a detailed summary of the time taken to drill each hole. The holes are listed in the order they were drilled. The operator performing the test was a demonstration operator employed

by Joy.

Future study on the application of this type of drilling (rotary-penetration) to oil shale operations should be undertaken.

COST ESTIMATES:

An estimate of operating labor and supplies and maintenance labor and supplies is attached.

WJ/vc

THE CLEVELAND - CLIFFS IRON CO.
WESTERN DIVISION

PROJECT: JOY DRILLING TEST

LOWER LEVEL MINING - 3,450 TONS/DAY 23,000 TONS/WEEK

OPERATING COST - DRILLING (WET ROTARY)

A. OPERATING LABOR

Job Description	Men Per Shift	Shift Schedule	Total Shifts	Shift Rate	Cost Per Week
Drill Operator (\$5.33)	<u>1</u>	<u>5.3</u>	<u>5.3</u>	\$42.64	\$ 226
Bit Sharpener (\$5.29)	<u>1</u>	<u>1.2</u>	<u>1.2</u>	42.32	51
Sub Total					\$ 277
Contributions @ <u>35 %</u>					97
Contributions for Absenteeism @ <u>1.4 %</u>					4
Total Labor Cost					\$ 378
Cost per Ton					<u>.0164</u>

B. OPERATING & MAINTENANCE SUPPLIES

1. Drill Steel = <u>2818</u> ft drilled/wk x \$.028 /ft drilled	= \$	79
2. Bits = <u>2818</u> ft drilled/wk x \$.037 /ft drilled	=	104
3. Detergent = <u>2818</u> ft drilled/wk x \$.0005/ft drilled	=	1
4. Compressor = <u>25.8</u> drilling hrs/wk x \$ <u>6.17</u> /drilling hr	=	159
5. Drill Unit & Carrier =		
a) Drilling = <u>25.8</u> drilling hrs/wk x \$ <u>4.80</u> /drilling hr	=	124
b) Place Change = <u>1</u> place change hrs/wk x \$ <u>3.31</u> /		
place change hr	=	3
6. Water = <u>2818</u> ft drilled/wk x <u>.19</u> gals/ft drilled x		
\$.0005/gal	=	1
7. Grinding Wheels = <u>2818</u> ft drilled/wk x \$.001 /ft drilled	=	2
8. Miscellaneous (Bits, lube, wrenches, paint, etc.)		
<u>11.74</u> rounds/wk x \$ <u>2.04</u> /round	=	2
Total Supply Cost	\$	475
Cost per Ton		<u>.0206</u>

LABOR COST/TON = \$0.0270
SUPPLY COST/TON = \$0.0206

ESTIMATED TOTAL
COST/TON = \$0.0476

THE CLEVELAND - CLIFFS IRON CO.
WESTERN DIVISION

PROJECT: JOY DRILLING TEST

LOWER LEVEL MINING - 3,450 TONS/DAY 23,000 TONS/WEEK

OPERATING COST - DRILLING (WET ROTARY)

A. OPERATING LABOR

Job Description	Men Per Shift	Shift Schedule	Total Shifts	Shift Rate	Cost Per Week
Drill Operator (\$2.25)	1	2-3	2.3	\$2.25	5.08
Drill Tender (\$2.25)	1	1-2	1.2	\$2.25	2.70
Sub Total					7.78
Contributions for Absenteeism				\$2.25	
Total Labor Cost					\$7.78
Cost per Ton					.0164

B. OPERATING & MAINTENANCE SUPPLIES

1. Drill Fuel = 2818 ft drilled/hr x 2.028 /ft drilled	=	5.71
2. Bits = 2818 ft drilled/hr x 2.027 /ft drilled	=	5.71
3. Petroleum = 2818 ft drilled/hr x 2.0005 /ft drilled	=	5.64
4. Compressor = 22.8 drilling hrs/wk x \$2.17/drilling hr	=	4.95
5. Drill Unit & Carrier =	=	
a) Drilling = 22.8 drilling hrs/wk x \$4.80 /drilling hr	=	109.44
b) Place Change = 1 place change hrs/wk x \$3.21	=	3.21
6. Water = 2818 ft drilled/hr x .12 gal/ft drilled x 2.0005/gal	=	6.81
7. Grinding Wheels = 2818 ft drilled/hr x 2.001 /ft drilled	=	5.64
8. Miscellaneous (bits, rods, wrenches, paint, etc.)	=	
9. Gravel/bedrock = 22.8 hrs/wk x \$2.00 /hr	=	4.56
Total Supply Cost		\$135.42
Cost per Ton		.0308

LABOR COST/TON = \$0.0164
SUPPLY COST/TON = \$0.0308
ESTIMATED TOTAL COST/TON = \$0.0472

THE CLEVELAND - CLIFFS IRON CO.
WESTERN DIVISION

PROJECT: JOY DRILLING TEST

LOWER LEVEL MINING - 3,450 TONS/DAY 23,000 TONS/WEEK

MAINTENANCE COST - DRILLING (WET ROTARY)

	COST PER WEEK
A. <u>MAINTENANCE LABOR</u>	
1. Drill Unit & Carrier	
a) Drilling = <u>25.8</u> drilling hrs/wk x \$ <u>7.24</u> /drilling hr =	\$ <u>187</u>
b) Place Change = <u>1</u> place change hrs/wk x \$ <u>2.43</u> / place change hr =	<u>2</u>
2. Compressor = <u>25.8</u> drilling hrs/wk x \$ <u>2.20</u> /drilling hr =	<u>57</u>
Total Labor Cost	\$ <u>246</u>
Cost per Ton	<u>.0106</u>

THE CLEVELAND - CLIFFS IRON CO.
WESTERN DIVISION

PROJECT: JOY DRILLING TEST

LOWER LEVEL MINING - 3,450 TONS/DAY 13,000 TONS/WEEK

MAINTENANCE COST - DRILLING (WET ROTARY)

COST PER
WEEK

A. MAINTENANCE LABOR

1. Drill Unit & Carrier

a) Drilling = 22.8 drilling hrs/wk x \$ 7.15/drilling hr = 163

b) Place Change = 1 place change hrs/wk x \$ 2.43/

place change hr = 2

2. Compressor = 22.8 drilling hrs/wk x \$ 2.20/drilling hr = 50

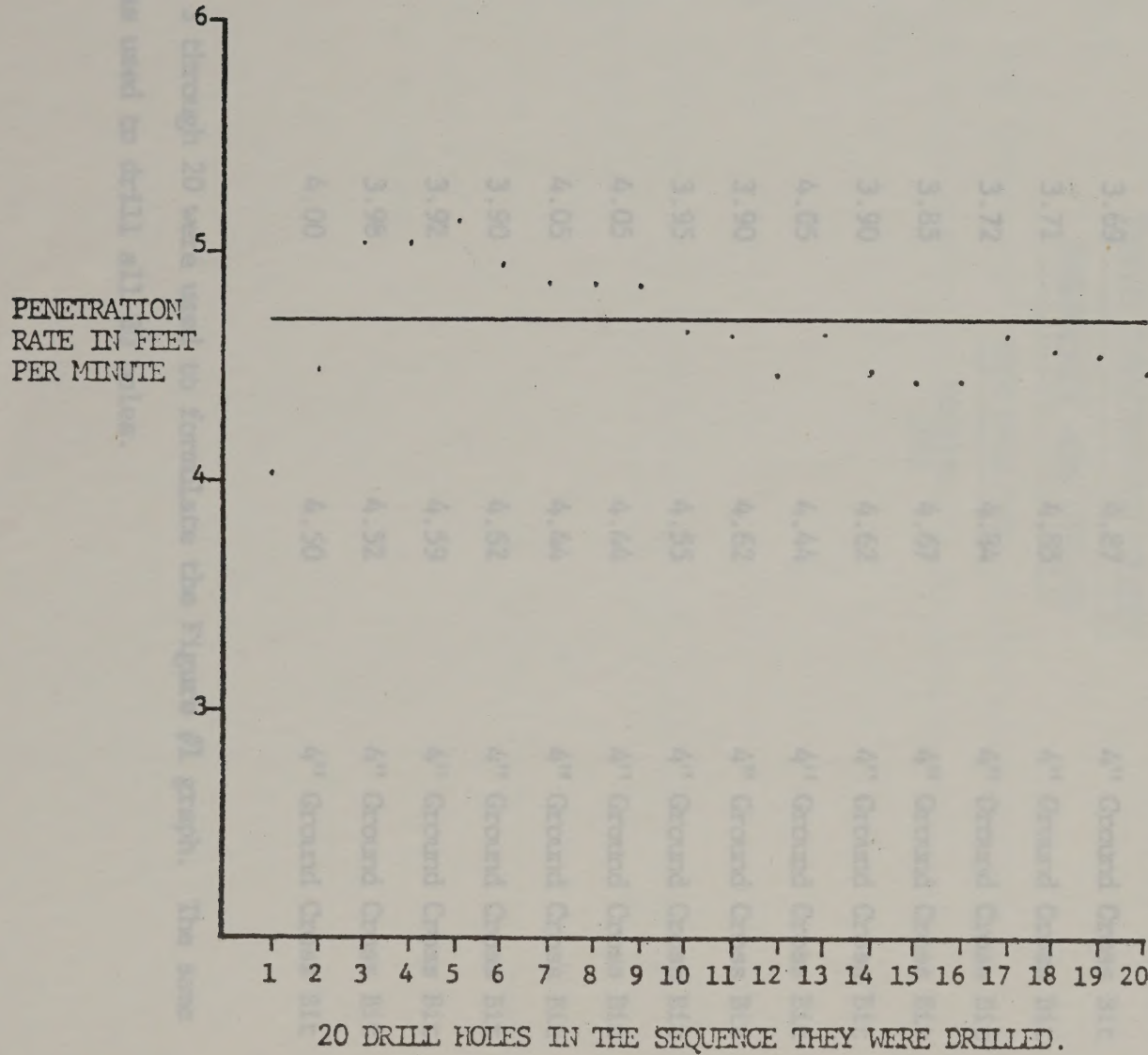
Total Labor Cost

Cost per Ton

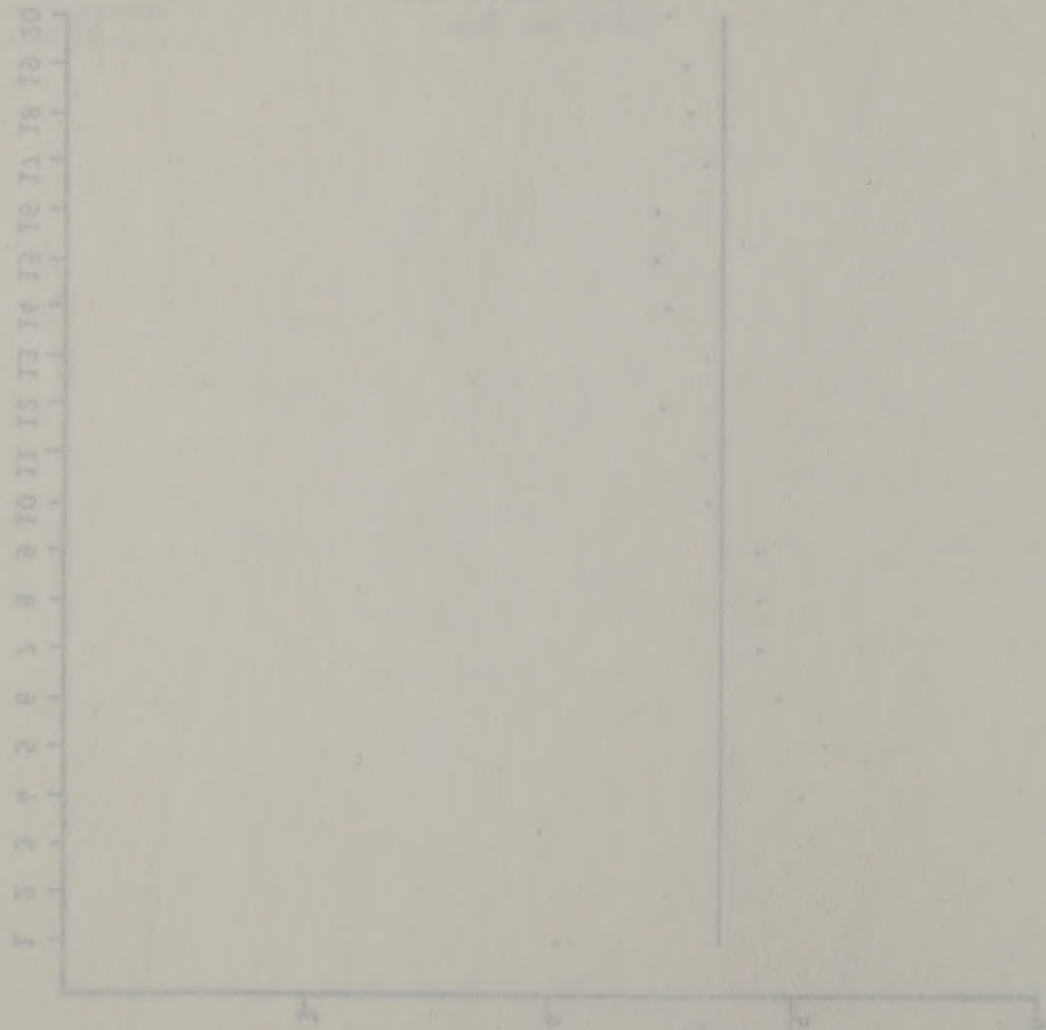
0.002

FIGURE #1

PLOT OF AVERAGE PENETRATION RATES FROM
20 HOLES DRILLED WITH THE SAME BIT



30 UNIT NOTES IN THE GEORGE DEL. MINE LIMITED



150 MINUTE
NOTE IN FULL
RECORDING

30 UNIT LIMITED WITH THE 20X 811
118 5002 501 WITH 0011111 2000 00

15. 10011

TABLE I

<u>HOLE NUMBER</u>	<u>TIME TO DRILL 18 FEET (MINUTES)</u>	<u>FEET PER MINUTE</u>	<u>BIT</u>
1	5.36	3.35	4" Ground Cross Bit
2	8.10	2.22	4" Button Bit
3	4.45	4.04	4" Ground Cross Bit
4	4.00	4.50	4" Ground Cross Bit
5	3.54	5.08	4" Ground Cross Bit
6	3.54	5.08	4" Ground Cross Bit
7	3.50	5.14	4" Ground Cross Bit
8	3.64	4.94	4" Ground Cross Bit
9	3.69	4.87	4" Ground Cross Bit
10	3.71	4.85	4" Ground Cross Bit
11	3.72	4.84	4" Ground Cross Bit
12	3.85	4.67	4" Ground Cross Bit
13	3.90	4.62	4" Ground Cross Bit
14	4.05	4.44	4" Ground Cross Bit
15	3.90	4.62	4" Ground Cross Bit
16	3.95	4.55	4" Ground Cross Bit
17	4.05	4.44	4" Ground Cross Bit
18	4.05	4.44	4" Ground Cross Bit
19	3.90	4.62	4" Ground Cross Bit
20	3.92	4.59	4" Ground Cross Bit
21	3.98	4.52	4" Ground Cross Bit
22	4.00	4.50	4" Ground Cross Bit

REMARKS: Holes 3 through 20 were used to formulate the Figure #1 graph. The same bit was used to drill all 20 holes.

TABLE I

BIT	FEET PER MINUTE	TIME TO DRILL 15 FEET (MINUTES)	HOLES NUMBER
4" Ground Cross Bit	3.35	2.36	1
4" Button Bit	2.35	6.10	2
4" Ground Cross Bit	4.04	4.45	3
4" Ground Cross Bit	4.50	4.00	4
4" Ground Cross Bit	5.08	3.54	5
4" Ground Cross Bit	5.08	3.54	6
4" Ground Cross Bit	5.14	3.50	7
4" Ground Cross Bit	4.94	3.64	8
4" Ground Cross Bit	4.87	3.69	9
4" Ground Cross Bit	4.85	3.71	10
4" Ground Cross Bit	4.84	3.73	11
4" Ground Cross Bit	4.67	3.85	12
4" Ground Cross Bit	4.63	3.90	13
4" Ground Cross Bit	4.44	4.05	14
4" Ground Cross Bit	4.45	3.90	15
4" Ground Cross Bit	4.55	3.95	16
4" Ground Cross Bit	4.44	4.05	17
4" Ground Cross Bit	4.44	4.05	18
4" Ground Cross Bit	4.63	3.80	19
4" Ground Cross Bit	4.59	3.95	20
4" Ground Cross Bit	4.55	3.98	21
4" Ground Cross Bit	4.50	4.00	22

REMARKS: Holes 3 through 20 were used to formulate the Figure 12 graph. The same bit was used to drill all 22 holes.

PARAHO DEMONSTRATION PROJECT

MAN/MACHINE WORK STUDIES

Amell Points Mine
Rifle, Colorado

October 1975

PROJECT:

Work Studies - Face Drilling

DESCRIPTION:

PARAHO DEMONSTRATION PROJECT

MAN/MACHINE WORK STUDIES

FACE DRILLING

October
1975

PURPOSE:

Calculate a face drilling cycle (23 hole round) for a commercial size mining operation.

AUDITOR:

W. W. Multon

PARADO DEMONSTRATION PROJECT
MACHINE WORK STUDIES

FACE DRILLING

October
1972

PROJECT LOCATION AND FULL FACE DRILLING FUNCTION

PARAHO DEMONSTRATION PROJECT

MAN/MACHINE WORK STUDIES

Anvil Points Mine
Rifle, Colorado

October 1975

PROJECT:

Work Studies - Face Drilling

DESCRIPTION:

Work studies utilizing a break out of elemental times were used to calculate a standard cycle time for face drilling one 26 hole round.

PURPOSE:

Calculate a face drilling cycle (23 hole round) for a commercial size mining operation.

AUTHOR:

W. W. Moulton

TABLE I

<u>Item</u>	<u>Manufacturer</u>	<u>Size</u>	<u>Remarks</u>
Bits	Gault Tool Co.	6-1/4"	4-wing drag bits
Steel	Gardner-Denver Co.	3"	

MINING INVESTIGATION PROJECT

MANUFACTURE WORK STUDIES

Amel Pointe Mine
Rifle, Colorado

October 1975

PROJECT:

Work Studies - Face Drilling

DESCRIPTION:

Work studies utilizing a break out of elemental times were

used to calculate a standard cycle time for face drilling one 36

hole round.

PURPOSE:

Calculate a face drilling cycle (23 hole round) for a commercial

size mining operation.

AUTHOR:

W. W. Hutton

PROJECT LOCATION AND FULL FACE DRILLING FUNCTION

This industrial engineering project was performed at the Paraho Demonstration Project's Anvil Points Mine, near Rifle, Colorado. The mine utilizes room and pillar mining for the extraction of oil shale rock. Room dimensions are 55 feet wide and 40 feet high. Figure 1, page 25 is a drawing of the 55' x 40' face, 26 drill hole pattern. The cut holes are approximately 24 feet deep and the other holes are between 20 and 22 feet deep depending upon the face configuration. Each round is expected to pull 20 feet.

EQUIPMENT DESCRIPTION

Face drilling is accomplished using a Gardner-Denver one boom jumbo equipped with a J.E.D.-1 rotary drill. This jumbo is mounted on a Mack 20 ton truck. Figure 3, page 27, is a drawing of the jumbo mounted on the truck.

An electric motor rated at 75 horsepower is used to supply power to run the hydraulic system. Another small electric motor powers the hydraulic fluid cooling system. Air supplied by the mine's air compressor and water are used to clean the hole.

Table I indicates the type and manufacturer of the bits and steel used on the jumbo.

TABLE I

<u>Item</u>	<u>Manufacturer</u>	<u>Size</u>	<u>Remarks</u>
Bits	Gault Tool Co.	4-1/4"	4-wing drag bits
Steel	Gardner-Denver Co.	3"	

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TABLE I

Item	Manufacturer	Size	Remarks
Bits	Gault Tool Co.	4-1/2"	4-wing drag bits
Steel	Gardner-Denver Co.	3"	

STANDARD CYCLE TIME

The face drilling cycle takes place after a heading has been roof bolted. Standard cycle time is the computation of the total time required to drill a 26 hole round. Total time is the summation of the elemental times derived from the timing of cycle elements. Cycle elements for face drilling are as follows:

1. Rig move in - set up and tear down - move out
2. Position and repositioning of boom at the hole location
3. Collaring the hole
4. Drilling the hole
5. Retracting the drill from completed hole
6. Bit change

The above cycle forms the major part of the total work cycle. The other part of the total work cycle is made up of various delays. These delays are noted in the man/machine charts where they occurred in the drilling sequence.

Standard industrial engineering procedures used in this analysis involved the calculation of mean times, standard deviation and percent standard deviation. In order to determine if a sufficient number of element cycles were recorded to allow a confidence level of 95 percent each element cycle was analyzed using the "t" test. This calculation is included on pages 8 to 11.

The man/machine time chart, pages 12 to 23, is a step by step breakdown of cycle element times with a cumulative time summation. This chart is followed by a summary sheet, page 24, which shows the total times, means, standard deviations and percent standard deviations for each cycle element.

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1. Rig move in - set up and tear down - move out
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3. Collaring the hole
4. Drilling the hole
5. Retracting the drill from completed hole
6. Rig change

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mean, standard deviation and percent standard deviation for each cycle

element.

ACTUAL WORK CYCLE

CONDITIONS

Floor - Irregular

Face - Irregular

POSSIBLE PRODUCTIVE WORK TIME

(Assume 100% utilization of time)

Allowances:

Travel to Work 30 Minutes

Travel to Lunch (3 occurrences per round) 5 Minutes

Lunch 30 Minutes *

Return to Work 5 Minutes

Supervision 15 Minutes

Personal 15 Minutes

Travel from Mine 30 Minutes

100 Minutes

* Not paid and not included in total.

Total Work Day

8 hours or 480 minutes $480 - 100 = 380$ minutes (possible productive work time)

The actual work cycle times are an accumulation of cycle times from five different rounds. Actual work times will not be included but a total time is included on the man/machine time chart and a cycle element breakdown is included in the summary sheet.

ACTUAL WORK CYCLE

POSITIONS

Floor - Irregular

Face - Irregular

POSSIBLE PRODUCTIVE WORK TIME

(Assume 100% utilization of time)

Allowances:

Travel to Work 30 Minutes

Travel to Lunch 5 Minutes

Lunch 30 Minutes *

Return to Work 5 Minutes

Supervision 15 Minutes

Personal 15 Minutes

Travel from Mine 30 Minutes

100 Minutes

* Not paid and not included in total.

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CYCLE ELEMENT (TOTALS)

For a 26 hole round the following numbers are averages taken from the actual work times.

1. Move in - set up - tear down move out (25.56 minutes each)	51.12 Minutes
2. Position and reposition on prospective hole	77.52 Minutes
3. Collar the hole	13.06 Minutes
4. Drill the hole	164.06 Minutes
5. Retract the drill	23.25 Minutes
6. Bit changes (3 occurrences per round)	17.29 Minutes
7. Delays (prorated)	<u>77.53 Minutes</u>
	423.83 Minutes

$$\frac{423.83}{26} = 16.30 \text{ minutes to drill one hole}$$

$$\frac{380.00}{423.83} = .896 \text{ rounds drilled per day}$$

The drilling element represents 38.17% of the total cycle time and position of the drill on the prospective hole represents 18.3% of the total cycle time. Together they represent 57% of the total time which would indicate a change in machine design. One change would be an increase in the number of drill booms on the jumbo. Delays consume 18.3% of the total cycle time. Forty percent of the 18.3% is spent moving the rig in order to drill holes along either rib. This moving could be eliminated by designing a drilling jumbo that will drill an entire round from one set up. Twelve percent of the 18.3% is spent filling the water tank. This delay could be eliminated by having a holding tank with water capacity for a shift of drilling.

CYCLE ELEMENT (TOTALS)

For a 36 hole round the following numbers are averages taken from five actual work times.

51.12 Minutes	1. Move in - set up - tear down move out (25.50 minutes each)
77.52 Minutes	2. Position and reposition on prospective hole
13.06 Minutes	3. Collar the hole
164.06 Minutes	4. Drill the hole
23.25 Minutes	5. Retract the drill
17.29 Minutes	6. Bit changes (3 occurrences per round)
<u>77.53 Minutes</u>	7. Delays (predicted)
423.83 Minutes	

$$423.83 = 16.30 \text{ minutes to drill one hole}$$

$$380.00 = .896 \text{ rounds drilled per day}$$

$$423.83$$

The drilling element represents 38.1% of the total cycle time and position of the drill on the prospective hole represents 18.3% of the total cycle time. Together they represent 56% of the total time which would indicate a change in machine design. One change would be an increase in the number of drill points on the jaws. Delays consume 18.3% of the total cycle time. Forty percent of the 18.3% is spent moving the rig in order to drill holes along either rib. This moving could be eliminated by designing a drilling frame that will drill an entire round from one set up. Twelve percent of the 18.3% is spent filling the water tank. This delay could be eliminated by having a holding tank with water capacity for a shift of drilling.

Major breakdowns are to be expected with a drill jumbo the size of the one that will be used in a commercial operation. In order that these breakdowns do not interfere with production, a back up drill jumbo will be required.

PROJECTED FACE DRILLING PROCEDURE FOR A COMMERCIAL OPERATION

In order to attain maximum efficiency in the face drilling function the drill jumbo will be a two boom, completely mobile, self-contained unit. It will be a diesel powered, rubber-tired chassis equipped with a compressor, hydraulic pumps and storage for fuel, water and hydraulic fluid. Power for the hydraulic pumps and compressor will be supplied with diesel engines. The following chart will be a work cycle for a drill jumbo equipped with two booms and operated by one man.

A round for a commercial operation will consist of 23 drill holes as shown in Figure 2 on page 26.

WORK CYCLE

(23 Drill Holes)

Face Drilling - 1 operator - 2 drills

ASSUME:

8 hour or 480 minute work day (collar to collar)

ALLOWANCES:

Travel to Work Place	10.00 Minutes
Lunch	30.00 Minutes *
Personal	15.00 Minutes
Supervision	10.00 Minutes
Return to Surface	<u>15.00 Minutes</u>
	80.00 Minutes

* 5 Minutes to Lunch, 20 Minutes Lunch, 5 Minutes to Work

Major breakdowns are to be expected with a drill jumbo the size

of the one that will be used in a commercial operation. In order that these breakdowns do not interfere with production, a back up drill jumbo will be required.

PROPOSED FACE DRILLING PROCEDURE FOR A COMMERCIAL OPERATION

In order to attain maximum efficiency in the face drilling function the drill jumbo will be a two boom, completely mobile, self-contained unit. It will be a diesel powered, rubber-tired chassis equipped with a compressor, hydraulic pump and storage for fuel, water and hydraulic fluid. Power for the hydraulic pump and compressor will be supplied with diesel engines. The following chart will be a work cycle for a drill jumbo equipped with two booms and operated by one man.

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WORK CYCLE

(23 Drill Holes)

Face Drilling - 1 operator - 2 drills

ASSUME:

8 hour or 480 minute work day (collar to collar)

ALLOWANCES:

Travel to Work Place	10.00 Minutes
Lunch	30.00 Minutes *
Personal	15.00 Minutes
Supervision	10.00 Minutes
Return to Surface	15.00 Minutes
	90.00 Minutes

* 5 Minutes to lunch, 25 Minutes to Work

480 - 80 = 400 Minutes (possible productive work time)

23 Drill Hole Work Cycle - (2,900 Tons Produced Rock)

(All Numbers Have Been Projected From Actual Cycle Times)

PROJECTED WORK CYCLE

Prepare rig (fuel, water & service) (30.00 prorated)	7.50 Minutes
Move in - set up	6.60 Minutes
Position and reposition (booms) on prospective hole	17.94 Minutes
Collar the hole	3.19 Minutes
Drill the hole *	38.20 Minutes
Retract the drill	5.69 Minutes
Bit change (2 times) **	3.00 Minutes
Tear down - move out	1.68 Minutes
Delays	<u>17.14 Minutes</u>
	100.95 Minutes

* Based on 6.02 feet per minute

** Utilizing a bit breakout wrench built on each boom

= 400 Minutes Possible Productive Work Time = 3.96 rounds drilled/8 hour shift at
100.95 Minutes

20 shifts per week = 79.20 rounds drilled per week.

480 - 80 = 400 Minutes (possible productive work time)

23 Drill Hole Work Cycle - (2,900 Tons Produced Rock)

(All Minutes Have Been Projected From Actual Cycle Times)

PROJECTED WORK CYCLE

7.30 Minutes	Prepare rig (fuel, water & services) (30.00 projected)
6.60 Minutes	Move in - set up
17.94 Minutes	Position and reposition (boom) on prospective hole
3.19 Minutes	Collar the hole
38.30 Minutes	Drill the hole *
2.69 Minutes	Retract the drill
3.00 Minutes	Bit change (2 times) **
1.88 Minutes	Tear down - move out
17.14 Minutes	Delays
100.95 Minutes	

* Based on 6.02 feet per minute

** Utilizing a bit bracket wrench built on each boom

400 Minutes Possible Productive Work Time = 3.95 rounds drilled per shift at 100.95 Minutes

30 shifts per week = 79.50 rounds drilled per week.

ROTARY DRILLING - GARDNER-DENVER JUMBO 4-1/4" BIT

Position and Reposition Time - All Holes

Calculation to estimate true mean 'M' from sample data.

Calculation to estimate true mean 'M' from sample data.

$$\sum x = 268.35$$

$$N = 90$$

$$\bar{x} = 2.9816$$

$$\sum x^2 = 1049.40$$

$$S(x) = \sqrt{\frac{\sum x^2 - \frac{(\sum x)^2}{N}}{N-1}}$$

$$S(x) = \sqrt{\frac{1049.40 - \frac{(268.35)^2}{90}}{90-1}}$$

$$S(x) = \sqrt{\frac{1049.40 - 799.68}{89}} = \sqrt{\frac{249.72}{89}} = \sqrt{2.81} = 1.68$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{1.68}{\sqrt{90}} = \frac{1.68}{9.4868} = 0.1771$$

M @ 95% Confidence Level

$$M = \bar{x} \pm T_{0.05} s(\bar{x})$$

$$M = 2.98 \pm 1.99 (0.1771)$$

$$M = 2.98 \pm .35 \text{ minutes per hole}$$

Position and Reposition Time - All Holes

Calculation to estimate true mean 'M' from sample data.

$$s_x = 268.35$$

$$N = 90$$

$$\bar{x} = 2.9816$$

$$s_x^2 = 1049.40$$

$$s(x) = \sqrt{\frac{s_x^2 - \bar{x} s_x}{N-1}}$$

$$s(x) = \sqrt{\frac{1049.40 - 2.98(268.35)}{90-1}}$$

$$s(x) = \sqrt{\frac{1049.40 - 799.68}{89}} = \sqrt{\frac{249.72}{89}} = \sqrt{2.81} = 1.68$$

$$s(x) = \frac{s(x)}{\sqrt{N}}$$

$$s(x) = \frac{1.68}{\sqrt{90}} = \frac{1.68}{9.4868} = 0.1771$$

M @ 95% Confidence Level

$$M = \bar{x} \pm 1.96 s(x)$$

$$M = 2.98 \pm 1.96(0.1771)$$

$$M = 2.98 \pm .35 \text{ minutes per hole}$$

ROTARY DRILLING - GARDNER-DENVER JUMBO 4-1/4" BIT

Collaring Time - All Holes

Calculation to estimate true mean 'M' from sample data.

$$\bar{x} = 45.21$$

$$N = 90$$

$$\bar{x} = .5023$$

$$s_x^2 = 28.80$$

$$S(x) = \sqrt{\frac{s_x^2 - \bar{x} s_x}{N-1}}$$

$$S(x) = \sqrt{\frac{28.80 - .50 (45.2)}{90-1}}$$

$$S(x) = \sqrt{\frac{28.80 - 22.60}{89}} = \sqrt{\frac{6.20}{89}} = \sqrt{.0697} = .264$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{.264}{\sqrt{90}} = \frac{.264}{9.4868} = .0278$$

M @ 95% Confidence Level

$$M = \bar{x} \pm T_{0.05} S(\bar{x})$$

$$M = .5023 \pm 1.990 (.0278)$$

$$M = .5023 \pm .0553 \text{ minutes per hole}$$

WATERY DRILLING - CASTER-BEWEY JUMBO 4-1/4" BIT

Collaring Time - All Holes

Calculation to estimate true mean "M" from sample data.

$$\begin{aligned} \bar{x} &= 45.21 \\ n &= 90 \\ \bar{x} &= .3023 \\ s^2 &= 28.80 \end{aligned}$$

$$\begin{aligned} s(x) &= \sqrt{\frac{s^2}{n-1}} = \sqrt{\frac{28.80}{90-1}} = \sqrt{.32} = .566 \\ s(x) &= \sqrt{\frac{s^2}{n}} = \sqrt{\frac{28.80}{90}} = \sqrt{.32} = .566 \\ s(x) &= \sqrt{\frac{s^2}{n}} = \sqrt{\frac{28.80}{90}} = \sqrt{.32} = .566 \end{aligned}$$

$$\begin{aligned} s(x) &= \frac{s(x)}{\sqrt{n}} \\ s(x) &= \frac{.566}{\sqrt{90}} = .0592 \end{aligned}$$

M @ 95% Confidence Level

$$M = \bar{x} \pm 1.96 s(x)$$

$$M = .3023 \pm 1.96 (.0592)$$

$$M = .3023 \pm .1162 \text{ estimate per hole}$$

ROTARY DRILLING - GARDNER-DENVER JUMBO 4-1/4" BIT

Drilling Time - All Holes

Calculation to estimate true mean 'M' from sample data.

$$\sum x = 586.85$$

$$N = 93$$

$$\bar{x} = 6.310$$

$$\sum x^2 = 4089.21$$

$$S(x) = \sqrt{\frac{\sum x^2 - \bar{x} \sum x}{N-1}}$$

$$S(x) = \sqrt{\frac{4089.21 - 6.31(586.85)}{93-1}}$$

$$S(x) = \sqrt{\frac{4089.21 - 3703.02}{92}} = \sqrt{\frac{386.19}{92}} = \sqrt{4.1977} = 2.04$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{2.04}{\sqrt{93}} = \frac{2.04}{9.643} = .2115$$

M @ 95% Confidence Level

$$M = \bar{x} \pm T_{0.05} S(\bar{x})$$

$$M = 6.310 \pm 1.9912 (.2115)$$

$$M = 6.310 \pm .4211 \text{ minutes per hole} = 2.97 \text{ to } 3.39 \text{ ft/minute}$$

Drilling Time - All Holes

Calculation to estimate true mean "N" from sample data.

$$\begin{aligned} \bar{x} &= 286.82 \\ n &= 23 \\ \bar{x} &= 6.310 \\ s_x^2 &= 4089.21 \end{aligned}$$

$$\begin{aligned} s(x) &= \sqrt{\frac{s_x^2}{n-1}} \\ s(x) &= \sqrt{\frac{4089.21 - 23(286.82)^2}{23-1}} \\ s(x) &= \sqrt{\frac{4089.21 - 23(82200.00)}{22}} = \sqrt{\frac{386.19}{22}} = \sqrt{17.55} = 4.19 \end{aligned}$$

$$\begin{aligned} s(x) &= \frac{s(x)}{\sqrt{n}} \\ s(x) &= \frac{4.19}{\sqrt{23}} = \frac{4.19}{4.79} = .87 \end{aligned}$$

N @ 95% Confidence Level

$$N = \bar{x} \pm 0.02 s(x)$$

$$N = 6.310 \pm (.02)(.87)$$

$$N = 6.310 \pm .0174 \text{ minutes per hole} = 2.97 \text{ to } 3.39 \text{ ft/minute}$$

ROTARY DRILLING - GARDNER-DENVER JUMBO 4-1/4" BIT

Bit Change Time - All Holes

October 1973

Calculation to estimate true mean 'M' from sample data.

$$\sum x = 74.92$$

$$N = 13$$

$$\bar{x} = 5.76$$

$$\sum x^2 = 497.57$$

$$S(x) = \sqrt{\frac{\sum x^2 - \bar{x} \sum x}{N-1}}$$

$$S(x) = \sqrt{\frac{497.57 - 5.76 (74.92)}{13-1}}$$

$$S(x) = \sqrt{\frac{497.57 - 431.54}{12}} = \sqrt{\frac{66.03}{12}} = \sqrt{5.5025} = 2.345$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{2.345}{\sqrt{13}} = \frac{2.345}{3.605} = .650$$

M @ 95% Confidence Level

$$M = \bar{x} \pm T_{0.05} S(\bar{x})$$

$$M = 5.76 \pm 2.160 (.650)$$

$$M = 5.76 \pm 1.404 \text{ minutes per hole (prorated)}$$

95% confident that $4.356 \leq M \leq 7.164$

Bit Change Time - All Holes

Calculation to estimate true mean "T" from sample data.

$$\begin{aligned} \bar{x} &= 2.76 \\ n &= 13 \\ \sum x &= 35.88 \\ \sum x^2 &= 100.72 \end{aligned}$$

$$\begin{aligned} s(x) &= \sqrt{\frac{\sum x^2 - n \bar{x}^2}{n-1}} \\ s(x) &= \sqrt{\frac{100.72 - 13(2.76)^2}{13-1}} \\ s(x) &= \sqrt{\frac{100.72 - 98.148}{12}} = \sqrt{\frac{2.572}{12}} = \sqrt{0.2143} = 0.463 \end{aligned}$$

$$\begin{aligned} s(x) &= \frac{s(x)}{\sqrt{n}} \\ s(x) &= \frac{0.463}{\sqrt{13}} = \frac{0.463}{3.606} = 0.128 \end{aligned}$$

95% Confidence Level

$$n = \bar{x} \pm 0.05 s(x)$$

$$n = 2.76 \pm 0.160 (0.630)$$

$$n = 2.76 \pm 0.104 \text{ minutes per hole (predicted)}$$

$$0.5 \leq \text{true mean } T \leq 4.3 \text{ min}$$

MAN/MACHINE TIME CHARTFace Drilling - Anvil Points MineOctober 1975

<u>HOLE NO.</u>	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
1	Rig set up	34.82	34.82
	Position	-	34.82
	Collar hole	.36	35.18
	Drill hole	10.58	45.76
	Retract drill	.67	46.43
2	Reposition	3.13	49.56
	Collar hole	.88	50.44
	Drill hole	6.81	57.25
	Retract drill	.83	58.08
3	Reposition	1.52	59.60
	Collar hole	.84	60.44
	Drill hole	7.57	68.01
	Retract drill	.84	68.85
	DELAY: Lost Paint Mark	9.00	77.85
4	Reposition	1.31	79.16
	Collar hole	.28	79.44
	Drill hole	9.42	88.86
	Retract drill	.87	89.73
	Change bit	4.48	94.21
5	Reposition	6.58	100.79
	Collar hole	.92	101.71
	Drill hole	9.02	110.73
	Retract drill	.69	111.42
6	Reposition	6.16	117.58
	Collar hole	1.00	118.58
	Drill hole	5.48	124.06
	Retract drill	1.18	125.24
7	Reposition	5.74	130.98
	Collar hole	1.28	132.26
	Drill hole	6.00	138.26
	Retract drill	.69	138.95
8	Reposition	5.88	144.83
	Collar hole	1.02	145.85
	Drill hole	4.18	150.03
	Retract drill	1.02	151.05

MANACHINE TIME CARD
Face Drilling - Avall Polaris Mine

October 1972

<u>CUMULATIVE</u> <u>TIME</u>	<u>TIME</u>	<u>EVENT</u>	<u>WELL NO.</u>
34.82	34.82	Rig set up	1
34.82	-	Position	
35.18	.36	Collar hole	
45.76	10.58	Drill hole	
46.43	.67	Retract drill	2
49.56	3.13	Reposition	
50.44	.88	Collar hole	
57.52	6.81	Drill hole	
58.08	.83	Retract drill	3
59.60	1.52	Reposition	
60.44	.84	Collar hole	
68.01	7.57	Drill hole	
68.82	.84	Retract drill	4
77.82	9.00	DELAY - Lost Polaris Mark	
79.16	1.31	Reposition	
79.44	.28	Collar hole	
88.86	9.42	Drill hole	5
89.73	.87	Retract drill	
94.21	4.48	Change bit	
100.79	6.58	Reposition	
101.71	.92	Collar hole	6
110.73	9.02	Drill hole	
111.42	.69	Retract drill	
117.58	6.16	Reposition	7
118.58	1.00	Collar hole	
124.06	5.48	Drill hole	
125.24	1.18	Retract drill	
130.98	5.74	Reposition	8
132.26	1.28	Collar hole	
138.26	6.00	Drill hole	
138.92	.69	Retract drill	
144.82	5.88	Reposition	9
145.82	1.02	Collar hole	
150.03	4.18	Drill hole	
151.02	1.02	Retract drill	

MAN/MACHINE TIME CHART
Face Drilling - Anvil Points Mine
October 1975

<u>HOLE NO.</u>	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
9	Reposition	3.24	154.29
	Collar hole	1.44	155.73
	Drill hole	5.28	161.01
	Retract drill	.88	161.89
	Change bit	4.80	166.69
	DELAY: Lost bit wrench	8.00	174.69
10	Reposition	5.94	180.63
	Collar hole	.97	181.60
	Drill hole	11.15	192.75
	Retract drill	.82	193.57
11	Reposition	5.15	198.72
	Collar hole	.94	199.66
	Drill hole	10.42	210.08
	Retract drill	1.08	211.16
	DELAY: Fill water tank	8.52	219.68
12	Reposition	5.78	225.46
	Collar hole	-	225.46
	Drill hole	4.86	230.32
	Retract drill	.78	231.10
13	Reposition	7.80	238.90
	Collar hole	.47	239.37
	Drill hole	6.01	245.38
	Retract drill	.82	246.20
14	Reposition	3.40	249.60
	Collar hole	.97	250.57
	Drill hole	9.33	259.90
	Retract drill	1.29	261.19
	DELAY: Move rig	32.03	293.22
15	Reposition	-	293.22
	Collar hole	.48	293.70
	Drill hole	5.04	298.74
	Retract drill	.91	299.65
16	Reposition	3.84	303.49
	Collar hole	.67	304.16
	Drill hole	5.25	309.41
	Retract drill	.88	310.29

MAN/MACHINE TIME CHART

Face Drilling - Awili Pottery Mine

October 1975

WTE NO.	WTE	TIME	CUMULATIVE TIME
9	Reposition	3.34	154.39
	Collar hole	1.44	155.83
	Drill hole	2.38	161.01
	Retract drill	.88	161.89
	Change bit	4.80	166.69
	DELAY: Lost bit		
	wrench	8.00	174.69
10	Reposition	2.94	180.63
	Collar hole	.97	181.60
	Drill hole	11.15	192.75
	Retract drill	.82	193.57
11	Reposition	2.15	198.72
	Collar hole	.94	199.66
	Drill hole	10.42	210.08
	Retract drill	1.08	211.16
	DELAY: Full water		
	tank	8.52	219.68
12	Reposition	2.78	222.46
	Collar hole	-	222.46
	Drill hole	4.86	230.32
	Retract drill	.78	231.10
13	Reposition	7.80	238.90
	Collar hole	.47	239.37
	Drill hole	6.01	245.38
	Retract drill	.82	246.20
14	Reposition	2.40	248.60
	Collar hole	.97	250.57
	Drill hole	9.33	259.90
	Retract drill	1.29	261.19
	DELAY: Move rig	32.03	293.22
15	Reposition	-	293.22
	Collar hole	.48	293.70
	Drill hole	2.04	298.74
	Retract drill	.91	299.65
16	Reposition	3.84	303.49
	Collar hole	.67	304.16
	Drill hole	2.22	309.41
	Retract drill	.88	310.29

MAN/MACHINE TIME CHART

Face Drilling - Anvil Points Mine

October 1975

<u>HOLE NO.</u>	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
17	Reposition	2.33	312.62
	Collar hole	.58	313.20
	Drill hole	4.00	317.20
	Retract drill	.98	318.18
18	Reposition	3.41	321.59
	Collar hole	.92	322.51
	Drill hole	5.96	328.47
	Retract drill	.91	329.38
19	Reposition	3.18	332.56
	Collar hole	.42	332.98
	Drill hole	3.62	336.60
	Retract drill	.73	337.33
20	Reposition	4.18	341.51
	Collar hole	.32	341.83
	Drill hole	5.04	346.87
	Change bit	5.22	352.09
	Retract drill	.92	353.01
21	Reposition	1.32	354.33
	Collar hole	.41	354.74
	Drill hole	6.63	361.37
	Retract drill	1.00	362.37
22	Reposition	1.26	363.63
	Collar hole	.52	364.15
	Drill hole	4.55	368.70
	Retract drill	1.32	370.02
23	Reposition	1.42	371.44
	Collar hole	.32	371.76
	Drill hole	4.45	376.21
	Retract drill	.85	377.06
24	Reposition	3.74	380.80
	Collar hole	.31	381.11
	Drill hole	12.36	393.47
	Retract drill	.78	394.25
	Reposition	2.20	396.45
	Collar hole	.84	397.29
	Drill hole	9.88	407.17
	Retract drill	.72	407.89
	DELAY: Repair hydraulic line	55.00	462.89

MINUTE TIME CHART

Face Drilling - Anvil Point Mine

October 1975

WELL NO.	EVENT	TIME	CUMULATIVE TIME
17	Reposition	2.33	312.62
	Collar hole	.58	313.20
	Drill hole	4.00	317.20
	Retract drill	.98	318.18
18	Reposition	3.41	321.59
	Collar hole	.92	322.51
	Drill hole	2.96	325.47
	Retract drill	.91	326.38
19	Reposition	3.18	329.56
	Collar hole	.42	330.98
	Drill hole	3.62	334.60
	Retract drill	.73	335.33
20	Reposition	4.18	340.51
	Collar hole	.32	340.83
	Drill hole	2.04	342.87
	Change bit	2.22	345.09
	Retract drill	.92	346.01
21	Reposition	1.32	347.33
	Collar hole	.41	347.74
	Drill hole	6.63	354.37
	Retract drill	1.00	355.37
22	Reposition	1.26	356.63
	Collar hole	.22	356.85
	Drill hole	4.22	361.07
	Retract drill	1.32	362.39
23	Reposition	1.42	363.81
	Collar hole	.32	364.13
	Drill hole	4.42	368.55
	Retract drill	.82	369.37
24	Reposition	3.74	373.11
	Collar hole	.31	373.42
	Drill hole	12.36	385.78
	Retract drill	.78	386.56

MAN/MACHINE TIME CHART
Face Drilling - Anvil Points Mine

October 1975

<u>HOLE NO.</u>	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
25	Reposition	4.21	398.46
	Collar hole	-	398.46
	Drill hole	11.31	409.77
	Retract drill	.72	410.49
	DELAY: Plugged air screen	25.00	435.49
26	Reposition	6.90	442.39
	Collar hole	.35	442.74
	Drill hole	4.73	447.47
	Retract drill	1.05	448.52
27	Reposition	1.41	449.93
	Collar hole	.32	450.25
	Drill hole	5.70	455.95
	Retract drill	.73	456.68
	Bit change	12.09	468.77
	DELAY: Personal	10.00	478.77
28	Reposition	2.00	480.77
	Collar hole	.34	481.11
	Drill hole	7.25	488.36
	Retract drill	.64	489.00
29	Reposition	5.65	494.65
	Collar hole	.48	495.13
	Drill hole	5.32	500.45
	Retract drill	.68	501.13
30	Reposition	1.42	502.55
	Collar hole	1.10	503.65
	Drill hole	6.92	510.57
	Retract drill	.92	511.49
	DELAY: Move rig	24.32	535.81
31	Reposition	4.21	540.02
	Collar hole	.79	540.81
	Drill hole	10.22	551.03
	Retract drill	1.09	552.12
32	Reposition	2.20	554.32
	Collar hole	.84	555.16
	Drill hole	9.88	565.04
	Retract drill	.77	565.81
	DELAY: Repair hydraulic leaks	55.00	620.81

MANUACHINE TIME CHART

Face Drilling - Anvil Pointe Mine

October 1975

WELL NO.	ELEMENT	TIME	CUMULATIVE TIME
25	Reposition	4.21	398.46
	Collar hole	-	398.46
	Drill hole	11.31	409.77
	Retract drill	.73	410.49
	DELAY: Plugged air screen	25.00	435.49
26	Reposition	6.90	442.39
	Collar hole	.35	442.74
	Drill hole	4.73	447.47
	Retract drill	1.02	448.50
27	Reposition	1.41	449.91
	Collar hole	.35	450.26
	Drill hole	5.70	455.96
	Retract drill	.73	456.69
	Bit change	12.09	468.77
	DELAY: Personnel	10.00	478.77
28	Reposition	2.00	480.77
	Collar hole	.34	481.11
	Drill hole	7.25	488.36
	Retract drill	.64	489.00
29	Reposition	2.62	491.62
	Collar hole	.48	492.10
	Drill hole	2.32	500.42
	Retract drill	.68	501.10
30	Reposition	1.42	502.52
	Collar hole	1.10	503.62
	Drill hole	6.92	510.54
	Retract drill	.92	511.46
	DELAY: Move rig	24.32	535.81
31	Reposition	4.21	540.02
	Collar hole	.79	540.81
	Drill hole	10.22	551.03
	Retract drill	1.09	552.12
32	Reposition	2.20	554.32
	Collar hole	.84	555.16
	Drill hole	9.88	565.04
	Retract drill	.77	565.81
	DELAY: Repair hydraulic lines	25.00	590.81

MAN/MACHINE TIME CHARTFace Drilling - Anvil Points MineOctober 1975

<u>HOLE NO.</u>	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
33	Reposition	5.73	626.54
	Collar hole	.56	627.10
	Drill hole	6.60	633.70
	Retract drill	.58	634.28
34	Reposition	2.01	636.29
	Collar hole	.75	637.04
	Drill hole	5.49	642.53
	Retract drill	.54	643.07
35	Reposition	1.64	644.71
	Collar hole	.62	645.33
	Drill hole	6.93	652.26
	Retract drill	.45	652.71
36	Reposition	2.89	655.60
	Collar hole	.51	656.11
	Drill hole	5.56	661.67
	Retract drill	.81	662.48
37	Reposition	2.29	664.77
	Collar hole	.61	665.38
	Drill hole	3.59	668.97
	Retract drill	.56	669.53
38	Reposition	3.18	672.71
	Collar hole	.62	673.33
	Drill hole	7.10	680.43
	Retract drill	.72	681.15
39	Reposition	3.30	684.45
	Collar hole	1.02	685.47
	Drill hole	6.07	691.54
	Retract drill	1.00	692.54
40	Reposition	5.00	697.54
	Collar hole	.68	698.22
	Drill hole	6.60	704.82
	Retract drill	.78	705.60
41	Reposition	1.55	707.15
	Collar hole	.70	707.85
	Drill hole	7.30	715.15
	Retract drill	.68	715.83
	DELAY: Repair hydraulic leaks	30.00	745.83

MANMACHINE TIME CHART
Face Drilling - Anvil Points Mine
October 1975

<u>WELL NO.</u>	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
33	Reposition	5.73	636.54
	Collar hole	.56	637.10
	Drill hole	6.60	643.70
	Retract drill	.58	644.28
34	Reposition	5.01	636.29
	Collar hole	.75	637.04
	Drill hole	5.49	642.53
	Retract drill	.54	643.07
35	Reposition	1.64	644.71
	Collar hole	.62	645.33
	Drill hole	6.93	652.26
	Retract drill	.45	652.71
36	Reposition	2.89	655.60
	Collar hole	.51	656.11
	Drill hole	5.56	661.67
	Retract drill	.81	662.48
37	Reposition	2.29	664.77
	Collar hole	.61	665.38
	Drill hole	3.59	668.97
	Retract drill	.56	669.53
38	Reposition	3.18	672.71
	Collar hole	.62	673.33
	Drill hole	7.10	680.43
	Retract drill	.72	681.15
39	Reposition	3.30	684.45
	Collar hole	1.02	685.47
	Drill hole	6.07	691.54
	Retract drill	1.00	692.54
40	Reposition	5.00	697.54
	Collar hole	.68	698.22
	Drill hole	6.60	704.82
	Retract drill	.78	705.60
41	Reposition	1.55	707.15
	Collar hole	.70	707.85
	Drill hole	7.30	715.15
	Retract drill	.68	715.83
	DELAY: Repair hydraulic lines	30.00	745.83

MAN/MACHINE TIME CHARTFace Drilling - Arvil Points MineOctober 1975

<u>HOLE NO.</u>	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
42	Reposition	5.26	751.09
	Collar hole	.72	751.81
	Drill hole	7.50	759.31
	Retract drill	.64	759.95
	Change bit	9.20	769.15
	DELAY: Lost air clean screen	20.00	789.15
43	Reposition	2.35	791.50
	Collar hole	.94	792.44
	Drill hole	5.65	798.09
	Retract drill	.52	798.61
44	Reposition	2.47	801.08
	Collar hole	.78	801.86
	Drill hole	6.21	808.07
	Retract drill	.76	808.83
45	Reposition	.94	809.77
	Collar hole	.44	810.21
	Drill hole	6.22	816.43
	Retract drill	1.05	817.48
46	Reposition	.88	818.36
	Collar hole	.36	818.72
	Drill hole	6.65	825.37
	Retract drill	1.11	826.48
	DELAY: Move rig	54.84	881.32
	DELAY: Personal	6.64	887.96
47	Reposition	1.04	889.00
	Collar hole	.36	889.36
	Drill hole	4.88	894.24
	Retract drill	.78	895.02
	Bit change	4.15	899.17
48	Reposition	2.44	901.61
	Collar hole	.40	902.01
	Drill hole	5.89	907.90
	Retract drill	.98	908.88
49	Reposition	1.05	909.93
	Collar hole	.36	910.29
	Drill hole	6.05	916.34
	Retract drill	1.02	917.36

MANACHINE TIME CHART

Face Drilling - Anvil Point Mine

October 1975

HOLE NO.	ELEMENT	TIME	CUMULATIVE TIME
42	Reposition	5.25	751.09
	Collar hole	.75	751.81
	Drill hole	7.30	759.31
	Retract drill	.64	759.95
	Change bit	9.20	769.15
	DELAY: Lost air		
	clean screen	20.00	789.15
43	Reposition	2.32	791.50
	Collar hole	.94	792.44
	Drill hole	2.62	798.09
	Retract drill	.22	798.61
44	Reposition	2.47	801.08
	Collar hole	.78	801.86
	Drill hole	6.21	808.07
	Retract drill	.76	808.83
45	Reposition	.94	809.77
	Collar hole	.44	810.21
	Drill hole	6.22	816.43
	Retract drill	1.02	817.48
46	Reposition	.88	818.36
	Collar hole	.36	818.72
	Drill hole	6.62	825.37
	Retract drill	1.17	826.48
	DELAY: Move rig	24.84	881.32
	DELAY: Personal	6.64	887.96
47	Reposition	1.04	889.00
	Collar hole	.36	889.36
	Drill hole	4.88	894.24
	Retract drill	.78	895.02
	Bit change	4.12	899.17
48	Reposition	2.44	901.61
	Collar hole	.40	902.01
	Drill hole	2.89	907.90
	Retract drill	.98	908.88
49	Reposition	1.02	909.93
	Collar hole	.36	910.29
	Drill hole	6.02	916.34
	Retract drill	1.02	917.36

MAN/MACHINE TIME CHARTFace Drilling - Anvil Points MineOctober 1975

<u>HOLE NO.</u>	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
50	Reposition	1.80	919.16
	Collar hole	1.80	919.50
	Drill hole	7.71	927.21
	Retract drill	.95	928.16
51	Reposition	1.75	929.91
	Collar hole	.35	930.26
	Drill hole	6.53	936.79
	Retract drill	.89	937.68
52	Reposition	2.09	939.77
	Collar hole	.37	940.14
	Drill hole	9.02	949.16
	Retract drill	.88	950.04
	DELAY: Reposition rig	6.10	956.14
53	Reposition	3.57	959.71
	Collar hole	.32	960.03
	Drill hole	5.32	965.35
	Retract drill	.88	966.23
	Lunch	54.38	1020.61
	Bit change	3.89	1024.50
54	Reposition	1.99	1026.49
	Collar hole	.33	1026.82
	Drill hole	4.47	1031.29
	Retract drill	1.04	1032.33
55	Reposition	2.92	1035.25
	Collar hole	.33	1035.58
	Drill hole	6.60	1042.18
	Retract drill	1.01	1043.19
56	Reposition	3.00	1046.19
	Collar hole	.34	1046.53
	Drill hole	6.92	1053.45
	Retract drill	1.03	1054.48
	Tear down - move out	17.22	1071.70

MANUWRITE TIME CHART

Face Drilling - Anvil Rodata Mine

October 1975

HOLE NO.	ELEMENT	TIME	CUMULATIVE TIME
20	Reposition	1.80	919.16
	Collar hole	1.80	919.50
	Drill hole	7.71	927.21
	Retract drill	.95	928.16
21	Reposition	1.75	929.91
	Collar hole	.35	930.26
	Drill hole	6.53	936.79
	Retract drill	.89	937.68
22	Reposition	2.09	939.77
	Collar hole	.37	940.14
	Drill hole	9.02	949.16
	Retract drill	.88	950.04
	DELAY: Reposition rig	6.10	956.14
23	Reposition	2.57	959.71
	Collar hole	.32	960.03
	Drill hole	5.32	965.35
	Retract drill	.68	966.23
	Lunch	24.38	1020.61
	Bit change	3.89	1024.50
24	Reposition	1.99	1026.49
	Collar hole	.33	1026.82
	Drill hole	4.47	1031.29
	Retract drill	1.04	1032.33
25	Reposition	2.92	1035.25
	Collar hole	.33	1035.58
	Drill hole	6.60	1042.18
	Retract drill	1.01	1043.19
26	Reposition	3.00	1046.19
	Collar hole	.34	1046.53
	Drill hole	6.92	1053.45
	Retract drill	1.03	1054.48
	Tear down - move out	17.32	1071.70

MAN/MACHINE TIME CHART

Face Drilling - Anvil Points Mine

October 1975

<u>HOLE NO.</u>	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
57	Reposition	2.59	1074.29
	Collar hole	.28	1074.57
	Drill hole	6.76	1081.33
	Retract drill	.83	1082.16
	Bit change	4.32	1086.48
58	Reposition	1.58	1088.06
	Collar hole	.25	1088.31
	Drill hole	4.24	1092.55
	Retract drill	.88	1093.43
59	Reposition	1.85	1095.28
	Collar hole	.28	1095.56
	Drill hole	5.28	1100.84
	Retract drill	.75	1101.59
60	Reposition	2.20	1103.79
	Collar hole	.27	1104.06
	Drill hole	8.20	1112.26
	Retract drill	.79	1113.05
61	Reposition	1.30	1114.35
	Collar hole	.25	1114.60
	Drill hole	6.24	1120.84
	Retract drill	.84	1121.68
62	Reposition	1.65	1123.33
	Collar hole	.55	1123.88
	Drill hole	11.13	1135.01
	Retract drill	.87	1135.88
	Bit change	5.08	1140.96
	DELAY: Fill water tank	5.42	1146.38
	DELAY: Personal	2.56	1148.94
63	Reposition	5.10	1154.04
	Collar hole	.26	1154.30
	Drill hole	5.51	1159.81
	Retract drill	.88	1160.69
64	Reposition	1.91	1162.60
	Collar hole	.64	1163.24
	Drill hole	7.65	1170.89
	Retract drill	.87	1171.76
	DELAY: Move truck	28.00	1199.76

MANWACHIE TIME GWAT
Face Drilling - Andri Pointe Mine
October 1972

HOLE NO.	ELMENT	TIME	CUMULATIVE TIME
57	Reposition	2.39	1074.29
	Collar hole	.28	1074.57
	Drill hole	6.76	1081.33
	Retract drill	.83	1082.16
	Bit change	4.32	1086.48
58	Reposition	1.58	1088.06
	Collar hole	.25	1088.31
	Drill hole	4.24	1092.55
	Retract drill	.88	1093.43
59	Reposition	1.85	1095.28
	Collar hole	.28	1095.56
	Drill hole	2.28	1100.84
	Retract drill	.75	1101.59
60	Reposition	2.20	1103.79
	Collar hole	.27	1104.06
	Drill hole	8.20	1112.26
	Retract drill	.79	1113.05
61	Reposition	1.30	1114.35
	Collar hole	.25	1114.60
	Drill hole	6.24	1120.84
	Retract drill	.84	1121.68
62	Reposition	1.65	1123.33
	Collar hole	.25	1123.58
	Drill hole	11.13	1134.71
	Retract drill	.87	1135.58
	Bit change	2.08	1140.66
	DELAY: Fill water tank	2.42	1143.08
	DELAY: Personnel	2.56	1145.64
63	Reposition	2.10	1154.04
	Collar hole	.26	1154.30
	Drill hole	2.51	1156.81
	Retract drill	.88	1160.69
64	Reposition	1.91	1162.60
	Collar hole	.64	1163.24
	Drill hole	7.62	1170.86
	Retract drill	.87	1171.73
	DELAY: Move truck	28.00	1199.73

MAN/MACHINE TIME CHARTFace Drilling - Anvil Points MineOctober 1975

<u>HOLE NO.</u>	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
65	Reposition	3.38	1203.14
	Collar hole	.29	1203.43
	Drill hole	5.58	1209.01
	Retract drill	-	1209.01
66	Reposition	-	1209.01
	Collar hole	.28	1209.29
	Drill hole	5.72	1215.01
	Retract drill	.92	1215.93
67	Reposition	1.75	1217.68
	Collar hole	.23	1217.91
	Drill hole	4.41	1222.32
	Retract drill	.90	1223.22
68	Reposition	4.00	1227.22
	Collar hole	.27	1227.49
	Drill hole	4.40	1231.89
	Retract drill	.88	1232.77
69	Reposition	3.42	1236.19
	Collar hole	.24	1236.43
	Drill hole	4.35	1240.78
	Retract drill	.92	1241.70
70	Reposition	3.88	1245.58
	Collar hole	.25	1245.83
	Drill hole	3.30	1249.13
	Retract drill	1.02	1250.15
71	Reposition	2.35	1252.50
	Collar hole	.30	1252.80
	Drill hole	4.25	1257.05
	Retract drill	1.10	1258.15
72	Reposition	3.05	1261.20
	Collar hole	.25	1261.45
	Drill hole	5.25	1266.70
	Retract drill	1.05	1267.75
	Bit change	4.35	1272.10
73	Reposition	3.12	1275.22
	Collar hole	.30	1275.52
	Drill hole	4.82	1280.34
	Retract drill	.92	1281.26

MAN/MACHINE TIME CHART

Face Drilling - Avondale Mines

October 1975

TIME	TIME	ELEMENT	HOLE NO.
1203.14	3.38	Reposition	65
1203.43	2.29	Collar hole	
1209.01	5.58	Drill hole	
1209.01	-	Retract drill	
1209.01	-	Reposition	66
1209.39	3.38	Collar hole	
1215.01	5.72	Drill hole	
1215.93	2.92	Retract drill	
1217.68	1.75	Reposition	67
1217.91	2.23	Collar hole	
1222.32	4.41	Drill hole	
1223.22	2.90	Retract drill	
1227.22	4.00	Reposition	68
1227.49	2.27	Collar hole	
1231.89	4.40	Drill hole	
1232.77	2.88	Retract drill	
1236.19	3.42	Reposition	69
1236.43	2.24	Collar hole	
1240.78	4.35	Drill hole	
1241.70	2.92	Retract drill	
1245.58	3.88	Reposition	70
1245.83	2.25	Collar hole	
1249.13	3.30	Drill hole	
1250.12	1.02	Retract drill	
1252.50	2.32	Reposition	71
1252.80	2.30	Collar hole	
1257.02	4.22	Drill hole	
1258.12	1.10	Retract drill	
1261.20	3.02	Reposition	72
1261.42	2.25	Collar hole	
1266.70	5.28	Drill hole	
1267.72	1.02	Retract drill	
1272.10	4.38	Bit change	
1275.22	3.12	Reposition	73
1275.32	2.30	Collar hole	
1280.36	4.82	Drill hole	
1281.58	2.92	Retract drill	

MAN/MACHINE TIME CHART

Face Drilling - Anvil Points Mine

October 1975

<u>HOLE NO.</u>	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
74	Reposition	1.06	1282.32
	Collar hole	.26	1282.58
	Drill hole	5.58	1288.16
	Retract drill	.99	1289.15
75	Reposition	1.32	1290.47
	Collar hole	.36	1290.83
	Drill hole	5.62	1296.45
	Retract drill	1.12	1297.57
76	Reposition	4.14	1301.71
	Collar hole	.29	1302.00
	DELAY: Fill		
	water tank	23.70	1325.70
	Bit change	5.23	1330.93
	Drill hole	5.34	1336.27
	Retract drill	.95	1337.22
	Lunch	60.00	1397.22
77	Reposition	7.40	1404.62
	Collar hole	.38	1405.00
	Drill hole	6.99	1411.99
	Retract drill	.95	1412.94
	Tear down move out	27.20	1440.14
	Move in - set up	23.01	1463.15
78	Reposition	5.90	1469.05
	Collar hole	.38	1469.43
	Drill hole	4.50	1473.93
	Retract drill	1.00	1474.93
79	Reposition	1.92	1476.85
	Collar hole	.39	1477.24
	Drill hole	4.34	1481.58
	Retract drill	1.04	1482.62
80	Reposition	1.82	1484.44
	Collar hole	.42	1484.86
	Drill hole	4.00	1488.86
	Retract drill	1.02	1489.88
81	Reposition	3.32	1493.20
	Collar hole	.26	1493.46
	Drill hole	3.83	1497.29
	Retract drill	1.05	1498.34

MANUFACTURE TIME CHART

Face Drilling - Anvil Point Mine

October 1975

HOLE NO.	ELEMENT	TIME	CUMULATIVE TIME
74	Reposition	1.06	1382.32
	Collar hole	.26	1382.58
	Drill hole	2.28	1388.16
	Retract drill	.99	1389.15
75	Reposition	1.32	1390.47
	Collar hole	.36	1390.83
	Drill hole	2.62	1396.45
	Retract drill	1.12	1397.57
76	Reposition	4.14	1301.71
	Collar hole	.29	1302.00
	DELAY: 7.11		
	water tank	23.70	1325.70
	Bit change	2.23	1330.93
	Drill hole	2.34	1336.27
	Retract drill	.92	1337.29
	Lunch	60.00	1397.29
77	Reposition	7.40	1404.69
	Collar hole	.38	1405.00
	Drill hole	6.92	1411.99
	Retract drill	.92	1412.94
	Turn down move out	27.20	1440.14
	Move in - set up	23.01	1463.15
78	Reposition	2.90	1469.05
	Collar hole	.38	1469.43
	Drill hole	4.20	1473.93
	Retract drill	1.00	1474.93
79	Reposition	1.92	1476.85
	Collar hole	.39	1477.24
	Drill hole	4.34	1481.58
	Retract drill	1.04	1482.62
80	Reposition	1.82	1484.44
	Collar hole	.42	1484.86
	Drill hole	4.00	1488.86
	Retract drill	1.02	1489.88
81	Reposition	2.32	1493.20
	Collar hole	.26	1493.46
	Drill hole	6.83	1497.29
	Retract drill	1.02	1498.31

MAN/MACHINE TIME CHARTFace Drilling - Anvil Points MineOctober 1975

<u>HOLE NO.</u>	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
82	Reposition	2.26	1500.60
	Collar hole	.34	1500.94
	Drill hole	3.65	1504.59
	Retract drill	1.00	1505.59
83	Reposition	3.05	1508.64
	Collar hole	.36	1509.00
	Drill hole	10.75	1519.75
	Retract drill	1.10	1520.85
	Bit change	6.07	1526.92
	DELAY: Fill water tank	6.47	1533.39
84	Reposition	2.55	1535.94
	Collar hole	-	1535.94
	Drill hole	8.50	1544.44
	Retract drill	.94	1545.38
85	Reposition	1.20	1546.58
	Collar hole	.44	1547.02
	Drill hole	6.00	1553.02
	Retract drill	.97	1553.99
86	Reposition	3.34	1557.33
	Collar hole	.30	1557.63
	Drill hole	3.35	1560.98
	Retract drill	.89	1561.87
87	Reposition	.84	1562.71
	Collar hole	.30	1563.01
	Drill hole	3.58	1566.59
	Retract drill	.88	1567.47
88	Reposition	3.62	1571.09
	Collar hole	.40	1571.49
	Drill hole	5.35	1576.84
	Retract drill	.94	1577.78
	Bit change	6.04	1583.82
	DELAY: Plugged water line	3.30	1587.12
89	Reposition	1.15	1588.27
	Collar hole	.37	1588.64
	Drill hole	4.24	1592.88
	Retract drill	1.06	1593.94

MAN/MACHINE TIME CHART

Face Drilling - Small Points Mine

October 1975

WELL NO.	ELEMENT	TIME	CUMULATIVE TIME
82	Reposition	2.36	1500.60
	Collar hole	.34	1500.94
	Drill hole	3.63	1504.57
	Retract drill	1.00	1505.57
83	Reposition	3.02	1508.59
	Collar hole	.36	1508.95
	Drill hole	10.72	1519.67
	Retract drill	1.10	1520.77
	Bit change	6.07	1526.84
	DELAY: Fill water tank	6.47	1533.31
84	Reposition	2.52	1535.83
	Collar hole	-	1535.83
	Drill hole	8.50	1544.33
	Retract drill	.94	1545.27
85	Reposition	1.20	1546.47
	Collar hole	.44	1546.91
	Drill hole	6.00	1552.91
	Retract drill	.97	1553.88
86	Reposition	3.34	1557.22
	Collar hole	.30	1557.52
	Drill hole	3.32	1560.84
	Retract drill	.89	1561.73
87	Reposition	.84	1562.57
	Collar hole	.30	1562.87
	Drill hole	3.58	1566.45
	Retract drill	.88	1567.33
88	Reposition	3.62	1571.01
	Collar hole	.40	1571.41
	Drill hole	5.32	1576.73
	Retract drill	.94	1577.67
	Bit change	6.04	1583.71
	DELAY: Flushed water line	3.30	1587.01
89	Reposition	1.12	1588.13
	Collar hole	.37	1588.50
	Drill hole	4.24	1592.74
	Retract drill	1.06	1593.80

Face Drilling - Anvil Points Mine

<u>HOLE NO.</u>	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
90	Reposition	1.75	1595.69
	Collar hole	.31	1596.00
	Drill hole	6.66	1602.66
	Retract drill	1.08	1603.74
91	Reposition	.90	1604.64
	Collar hole	.37	1605.01
	Drill Hole	6.54	1611.55
	Retract drill	1.05	1612.60
92	Reposition	1.18	1613.78
	Collar hole	.35	1614.13
	Drill hole	7.82	1621.95
	Retract drill	.93	1622.88
93	Reposition	1.05	1623.93
	Collar hole	.39	1624.32
	Drill hole	7.92	1632.24
	Retract drill	-	1632.24

MANAGEMENT TIME CARD

Face Drilling - Anvil Point Mine

October 1975

CUMULATIVE TIME	TIME	ELEMENT	TIME NO.
1595.60	1.75	Reposition	90
1596.00	.31	Collar hole	
1602.66	6.66	Drill hole	
1603.74	1.08	Retract drill	
1604.64	.90	Reposition	91
1605.01	.37	Collar hole	
1611.55	6.54	Drill hole	
1612.60	1.05	Retract drill	
1613.78	1.18	Reposition	92
1614.19	.41	Collar hole	
1621.95	7.76	Drill hole	
1622.88	.93	Retract drill	
1623.93	1.05	Reposition	93
1624.32	.39	Collar hole	
1632.24	7.92	Drill hole	
1632.24	-	Retract drill	

MAN/MACHINE TIME CHART

Face Drilling - Anvil Points Mine

October 1975

SUMMARY SHEET

Element	Total Time	Occurrences of Cycle Elements	Mean	Standard Deviation	Per Cent Standard Deviation
1. Move in - set up - tear down - move out	102.25	4	25.56	7.40	29%
2. Position and reposi- tion on prospective hole	268.35	90	2.98	1.70	57%
3. Collar the hole	45.21	90	.50	.27	53%
4. Drill the hole	586.85	93	6.31	2.05	32%
5. Retract the drill	81.38	91	.89	.16	18%
6. Bit change	74.92	13	5.76	2.34	40%
7. Delays	358.90	18	19.38	-	-
8. Lunch	<u>114.38</u>	2	57.19	-	-
	1,632.24				

MANUACHINE TIME CHART

Face Drilling - Amvli Potomc Mine

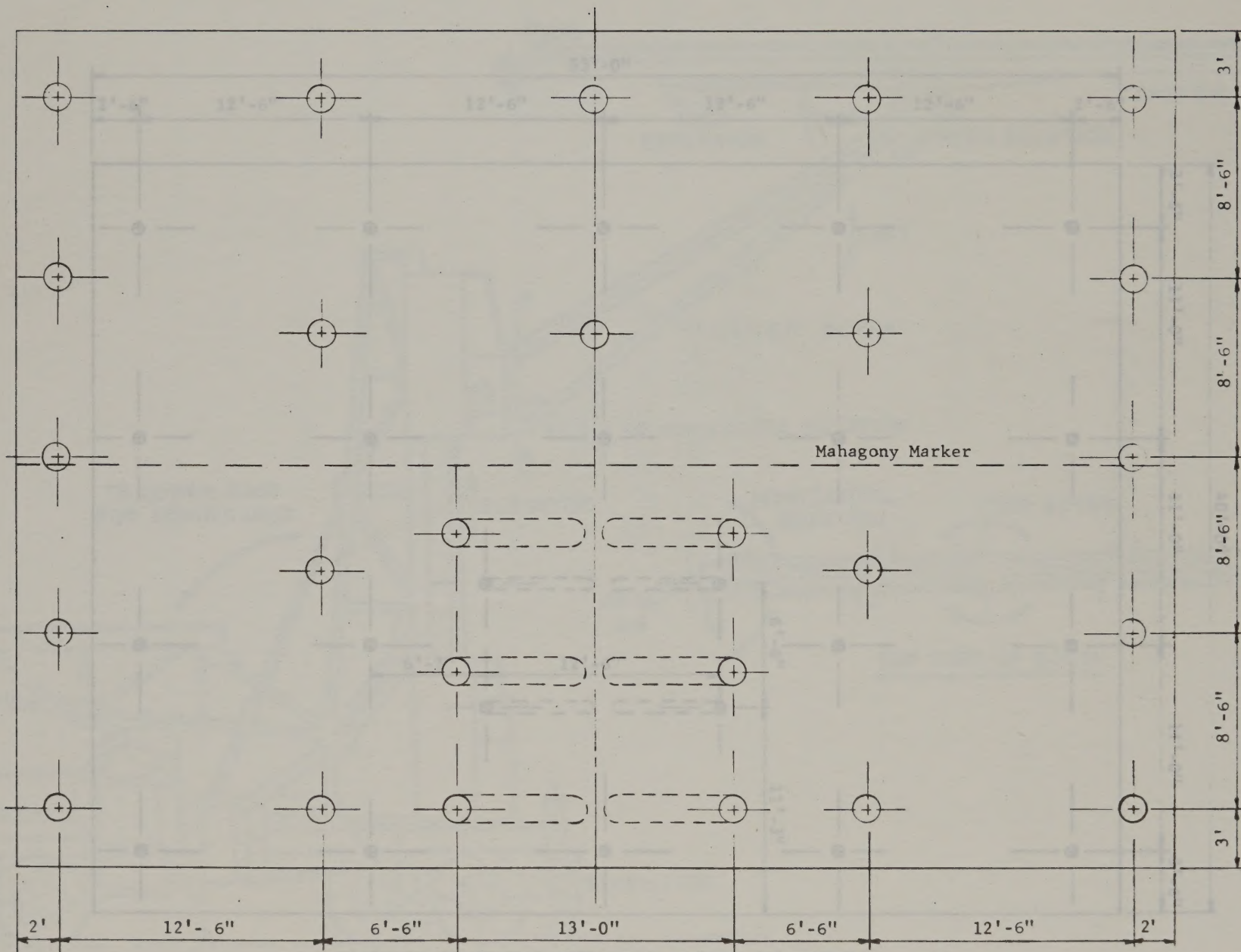
October 1975

SUMMARY SHEET

Element	Total Time	Occurrences of Cycle Elements	Mean	Standard Deviation	Per Cent Standard Deviation
1. Move in - set up - test down - move out	102.25	4	25.56	7.40	29%
2. Position and reposition on prospective hole	368.35	90	2.98	1.70	57%
3. Collar the hole	45.21	90	.50	.27	53%
4. Drill the hole	586.85	93	6.31	2.05	32%
5. Retract the drill	81.38	91	.89	.16	18%
6. Bit change	74.92	13	5.76	2.34	40%
7. Delays	358.90	18	19.38	-	-
8. Lunch	114.38	2	57.19	-	-
	1,632.24				

-25-

FIGURE 1



26 DRILL HOLE PATTERN

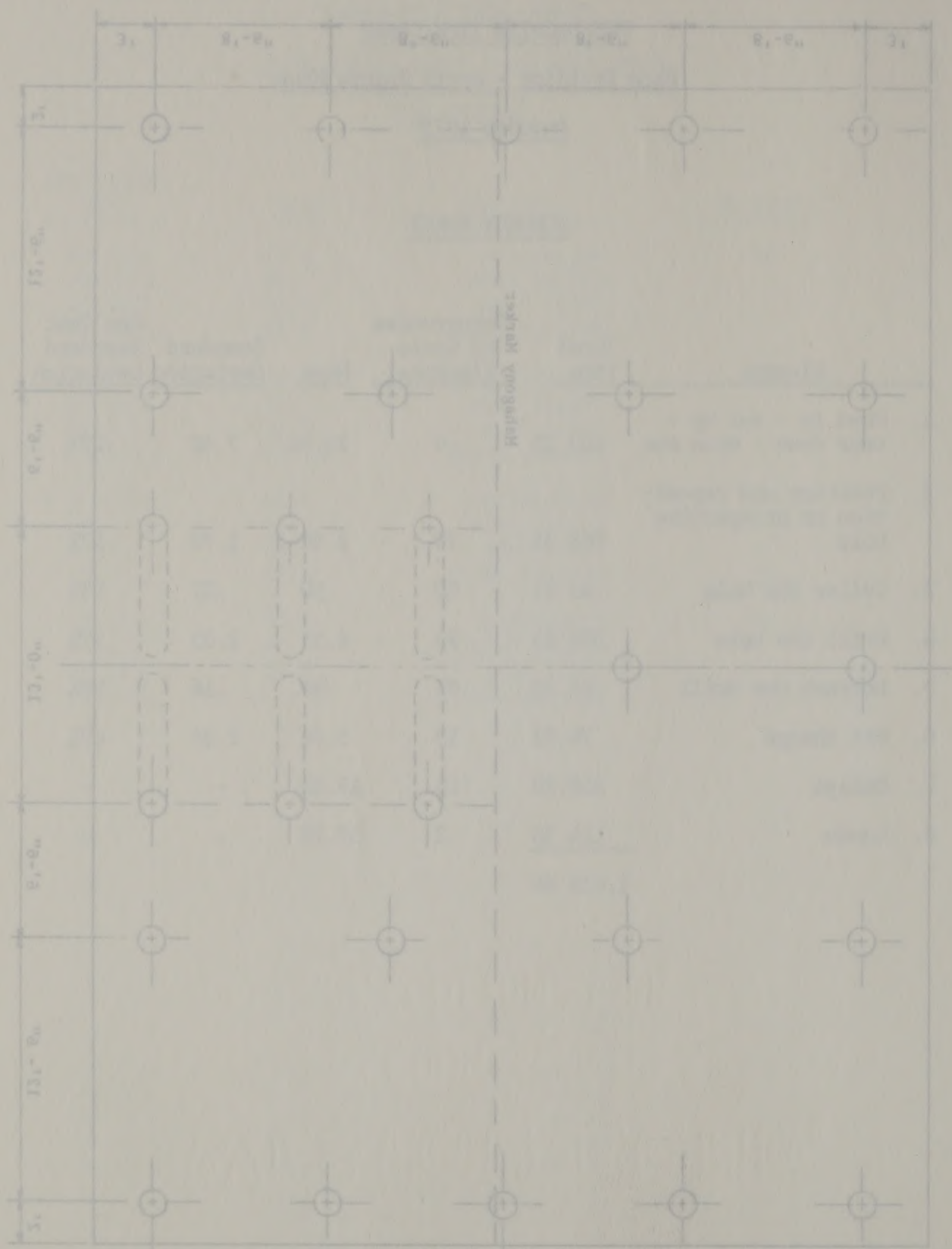
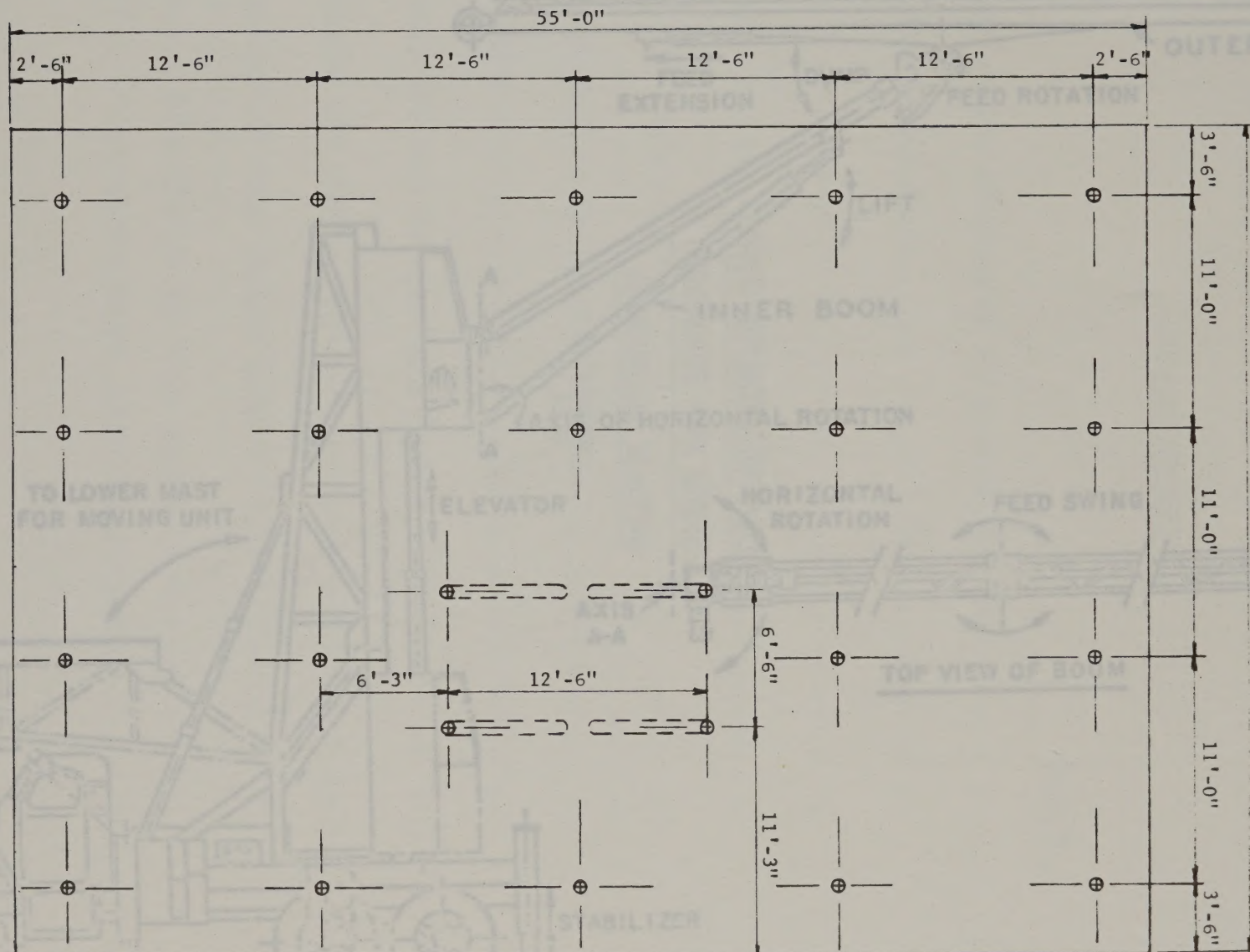


FIGURE 1

FIGURE 2



PROJECTED COMMERCIAL DRILL HOLE PATTERN (23 HOLES)

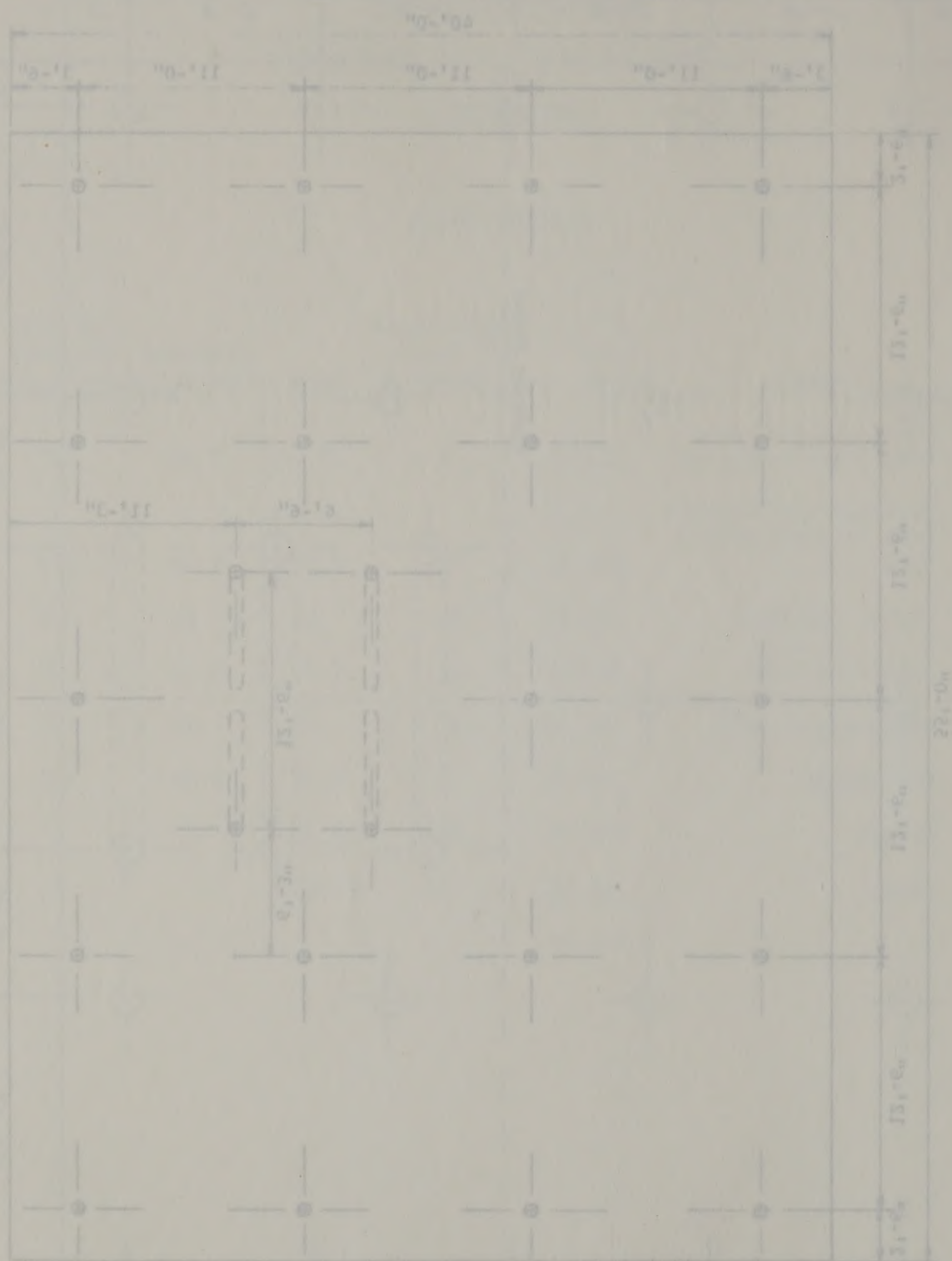


FIGURE 5

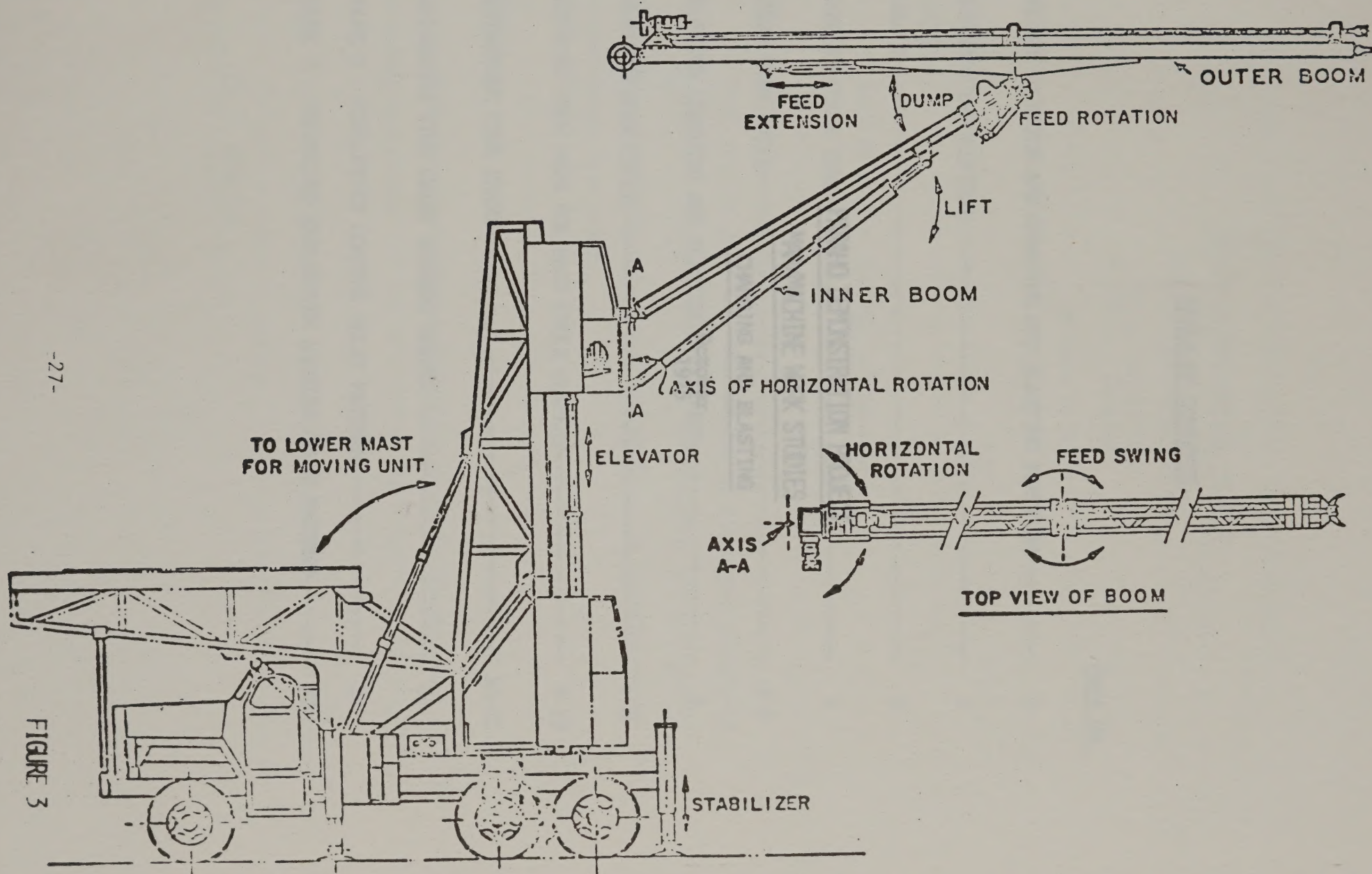


FIGURE 3

1 BOOM JUMBO

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PARAHO DEMONSTRATION PROJECT

MAN/MACHINE WORK STUDIES

CHARGING AND BLASTING

October
1975

PARAND DEMONSTRATION PROJECT

MAN/MACHINE WORK STUDIES

CHARGING AND BLASTING

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Rifle, Colorado

October 1973

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W. W. Moulton

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PROJECT LOCATION AND CHARGING AND BLASTING FUNCTION

PARAHO DEMONSTRATION PROJECT

MAN/MACHINE WORK STUDIES

Arvil Points Mine
Rifle, Colorado

October 1975

PROJECT:

Work Studies - Charging and Blasting

DESCRIPTION:

Work studies utilizing a break out of elemental times were used to calculate a standard cycle time for charging and blasting 26 drill holes. Twenty-six drill holes are used in the blasting of one standard twenty foot round.

PURPOSE:

Calculate a charging and blasting cycle for a commercial size mining operation.

AUTHOR:

W. W. Moulton

MINING INVESTIGATION PROJECT

MINING MACHINE WORK STUDIES

Avon, Pointe Mine
El Paso, Colorado

October 1972

PROJECT:

Work Studies - Charging and Blasting

DESCRIPTION:

Work studies utilizing a break out of elemental times were used to calculate a standard cycle time for charging and blasting 26 drill holes. Twenty-six drill holes are used in the blasting of one standard twenty foot round.

PURPOSE:

Calculate a charging and blasting cycle for a commercial size mining operation.

AUTHOR:

W. W. Houston

TABLE I

PROJECT LOCATION AND CHARGING AND BLASTING FUNCTION

This industrial engineering project was performed at the Paraho Demonstration Project's Anvil Points Mine near Rifle, Colorado. The mine utilizes room and pillar mining for the extraction of oil shale rock. Room dimensions are 55 feet wide by 40 feet high. Each round is designed and drilled to advance twenty feet and produce approximately 2,942 tons of oil shale rock. AN/FO, a mixture of ammonium nitrate and fuel oil is used as the principal blasting agent.

EQUIPMENT DESCRIPTION

Explosives loading is accomplished by means of an aerial platform mounted on a diesel powered carrier (powder monkey). The carrier is equipped with an air injection system which is used to place ammonium nitrate (prills) explosive into drill holes. The air injection system is equipped with a forty foot, two inch flexible hose for the actual loading cycle.

The "powder monkey" is not a self-contained unit. It has to be hooked up the mine's compressed air system for its injection power. Drawbacks in this unit which curtail efficiency are its lack of adequate storage for explosives and its inadequate range regarding the loading of drill holes.

Table I indicates the type and manufacturer of the explosives, primers, delay detonators, prima-cord, fuse and other equipment used in the explosives loading cycle.

PROJECT LOCATION AND CHARGING AND BLASTING FUNCTION

This industrial engineering project was performed at the Paria Penetration Project's Anvil Point Mine near Rifle, Colorado. The mine utilizes room and pillar mining for the extraction of oil shale rock. Room dimensions are 55 feet wide by 40 feet high. Each room is designed and drilled to advance twenty feet and produce approximately 2,942 tons of oil shale rock. ANFO, a mixture of ammonium nitrate and fuel oil is used as the principal blasting agent.

EQUIPMENT DESCRIPTION

Explosives loading is accomplished by means of an aerial platform mounted on a diesel powered carrier (powder monkey). The carrier is equipped with an air injection system which is used to place ammonium nitrate (ANFO) explosive into drill holes. The air injection system is equipped with a forty foot, two inch flexible hose for the actual loading cycle. The "powder monkey" is not a self-contained unit. It has to be hooked up to the mine's compressed air system for its injection power. Drawbacks in this unit which curtail efficiency are its lack of adequate storage for explosives and its inadequate range regarding the loading of drill holes. Table 1 indicates the type and manufacturer of the explosives, primers, delay detonators, primer-cord, fuse and other equipment used in the explosives loading cycle.

TABLE I

<u>Item</u>	<u>Manufacturer</u>	<u>Trade Name</u>	<u>Remarks</u>
Explosives	Du Pont	AN/FO	Mixture of Ammonium Nitrate & Fuel Oil - 50 lb. sacks
Primer	Trojan	Primer Cans	
Delay Detonators	Ensign Bickford Co.	Primadets	
Prima-Cord	Du Pont	E-Cord	
Detonator	Du Pont	Blasting Caps	

STANDARD CYCLE TIME

The explosives loading function takes place after the face drilling function.

Standard cycle time is the computation of the total time required to load and tie in the explosives in a twenty-six hole full face twenty foot round. Total time is the summation of elemental times derived from the timing of cycle elements. Cycle elements for the explosives loading function are as follows:

1. get powder
2. move in - set up - tear down - move out
3. position and reposition on drill hole
4. prepare primer
5. install primer in hole
6. load explosives into drill hole
7. tie in the primer
8. fill explosives holding tank
9. tie in entire round

TABLE I

Item	Manufacturer	Trade Name	Remarks
Explosives	De Pont	ANFO	Mixture of Ammonium Nitrate & Fuel Oil - 50 lb. sacks
Primer	Trojan	Primer Caps	
Delay Detonators	Briggs Dickford Co.	Primer Caps	
Primer-Cord	De Pont	E-Cord	
Detonator	De Pont	Blasting Caps	

STANDARD CYCLE TIME

The explosives loading function takes place after the face

drilling function.

Standard cycle time is the computation of the total time

required to load and tie in the explosives in a twenty-six hole full face

twenty foot round. Total time is the summation of elemental times

derived from the timing of cycle elements. Cycle elements for the explosives

loading function are as follows:

1. get powder
2. move in - set up - bear down - move out
3. position and reposition on drill hole
4. prepare primer
5. install primer in hole
6. load explosives into drill hole
7. tie in the primer
8. fill explosives holding tank
9. tie in entire round

Allowances The above cycle elements form the major portion of the total work cycle. The remaining portion of the total work cycle is made up of various delays. These delays are noted in the man/machine time charts where they occurred in the loading sequence.

Standard industrial engineering procedures used in this analysis included calculation of mean times, standard deviation and per cent standard deviation. In order to determine if a sufficient number of element cycles were recorded to allow a confidence level of 95% each element cycle was analyzed using the "t" test. This calculation is included on pages 9 to 13.

The man/machine time chart, pages 14 to 22, is a step by step breakdown of cycle element times with a cumulative time summation. This chart is followed by a summary sheet, page 23, which shows the total time, mean, standard deviation and percent standard deviation for each cycle element.

ACTUAL WORK CYCLE

CYCLE ELEMENT (TOTALS) Charging and Blasting - 2 men

CONDITIONS:

Floor - Irregular

Back - Smooth

Face and Ribs - Normal (scaled)

POSSIBLE PRODUCTIVE WORK TIME

(Assume 100% utilization of available time)

The above cycle elements form the major portion of the total work cycle. The remaining portion of the total work cycle is made up of various delays. These delays are noted in the machine time charts where they occurred in the loading sequence. Standard industrial engineering procedures used in this

analysis included calculation of mean times, standard deviation and percent standard deviation. In order to determine if a sufficient number of element cycles were recorded to allow a confidence level of 95% each element cycle was analyzed using the "t" test. This calculation is included on pages 9 to 13.

The man/machine time chart, pages 14 to 22, is a step by step breakdown of cycle element times with a cumulative time summation. This chart is followed by a summary sheet, page 23, which shows the total time, mean, standard deviation and percent standard deviation for each cycle element.

ACTUAL WORK CYCLE

Drilling and Blasting - 2 men

CONDITIONS:

Floor - Irregular

Back - Smooth

Face and Ribs - Normal (scaled)

POSSIBLE PRODUCTIVE WORK TIME

(Assume 100% utilization of available time)

Allowances:

Travel to Work	30 Minutes
Travel to Lunch	5 Minutes
Lunch	30 Minutes *
Return to Work	5 Minutes
Supervision	15 Minutes
Personal	15 Minutes
Travel from Mine	30 Minutes
	100 Minutes

* Not Paid and Not Included in Total

Total Work Day - 8 hours or 480 minutes = $480 - 100 = 380$ minutes
(possible productive work time)

Actual Work Times - as segments of three charging and blasting sequences are included in this report the actual working times will not be included. A total work time in minutes is included.

CYCLE ELEMENT (TOTALS):

Charging and blasting sequence - one 26 hole round (all times projected from actual cycle times).

1. Get powder from magazine	36.79 Minutes
2. Move in, set up, tear down, move out	34.58 Minutes
3. Position - reposition	45.50 Minutes
4. Prepare primer	18.05 Minutes
5. Install primer	17.68 Minutes
6. Load explosive into hole	70.72 Minutes
7. Tie in primer	16.38 Minutes

Alfonso:

Travel to Work	30 Minutes
Travel to Lunch	5 Minutes
Lunch	30 Minutes *
Return to Work	5 Minutes
Supervision	15 Minutes
Personal	15 Minutes
Travel from Mine	30 Minutes
	100 Minutes

* Not Paid and Not Included in Total

Total Work Day - 8 hours or 480 minutes = 480 - 100 = 380 minutes
(possible productive work time)

Actual Work Times - as segments of time charging and blasting sequences are included in this report the actual working times will not be included. A total work time in minutes is included.

Cycle Element (Times):

Charging and blasting sequence - one 36 hole round (all times

projected from actual cycle times).

1. Get powder from magazine	36.79 Minutes
2. Drive in, set up, tear down, move out	34.58 Minutes
3. Position - reposition	45.50 Minutes
4. Prepare primer	18.05 Minutes
5. Install primer	17.68 Minutes
6. Load explosives into hole	70.72 Minutes
7. Tie in primer	16.38 Minutes

8. Tie in round	7.00 Minutes
9. Fill explosives holding tank (3 times)	<u>17.52 Minutes</u>
	264.22 Minutes
Lunch (10 minutes paid)*	40.00 Minutes
Delays	<u>42.56 Minutes</u>
	346.78 Minutes
(Minus 30 minute not paid lunch)	<u>30.00 Minutes</u>
	316.78 Minutes

*Travel Time

$$\frac{316.78}{26} = 12.18 \text{ minutes/hole}$$

$$\frac{380.00}{316.78} = 1.199 \text{ rounds charged and blasted per day or 5.995 rounds/week}$$

The amount of powder used in this round was forty-five 50-lb. bags or 2,250 pounds of AN/FO, plus 75 pounds of primer or 2,325 pounds total. The amount of broken rock was estimated at 2,942 tons which equals a powder factor of .764 pounds AN/FO per ton of rock.

In the charging and blasting sequence 53.7 per cent of the total time is consumed in four cycle elements. These elements are:

1. Get powder from magazine
2. Position and reposition explosive injection hose
3. Load explosives into the hole
4. Fill the explosives holding tank.

The injection rate for AN/FO is approximately 25 pounds per minute. The design of the powder monkey could greatly reduce the total time consumed by the four above elements. Delays in the work cycle accounted for 13.4 per cent of the total sequence time. This time could be reduced with a self-contained powder monkey.

7.00 Minutes
 17.52 Minutes
 366.33 Minutes
 40.00 Minutes
 42.56 Minutes
 366.78 Minutes
 30.00 Minutes
 316.78 Minutes

8. Tie in round
 9. Fill explosives holding tank (3 times)
 Lunch (10 minutes paid)*
 Delays
 (Minus 30 minutes not paid lunch)

*Travel Time

$$316.78 - 12.18 \text{ minutes/round} = 304.60$$

$$380.00 - 1.199 \text{ rounds charged and blasted per day or 2.992 rounds/week} = 378.80$$

The amount of powder used in this round was forty-five 50-lb. bags or 2,250 pounds of ANFO, plus 75 pounds of primer or 2,325 pounds total. The amount of broken rock was estimated at 2,943 tons which equals a powder factor of .764 pounds ANFO per ton of rock. In the charging and blasting sequence 23.7 per cent of the total time is consumed in four cycle elements. These elements are:

1. Get powder from magazine
2. Position and reposition explosive injection hose
3. Load explosives into the hole
4. Fill the explosives holding tank.

The injection rate for ANFO is approximately 35 pounds per

minute. The design of the powder monkey could greatly reduce the total time consumed by the four above elements. Delays in the work cycle accounted for 13.4 per cent of the total sequence time. This time could be reduced with a self-contained powder monkey.

PROJECTED CHARGING AND BLASTING PROCEDURE

FOR A COMMERCIAL OPERATION

In order to attain maximum efficiency in the charging and blasting function the powder monkey will be a completely mobile, self-contained unit. It will be a diesel powered carrier equipped with an aerial platform capable of reaching any location on the face from one setup position. This would eliminate moving the truck during the charging sequence. The carrier will be equipped with a self-contained air injection system capable of injecting 150 pounds of explosives per minute and an explosives holding capacity of 7,000 pounds. This will be sufficient explosives for an eight hour shift and enough to load four rounds. These numbers are based on a round with dimensions of 55 feet wide by 40 feet high and a depth of 20 feet. At 14.957 cubic feet per ton of in-place oil shale rock one round will produce approximately 2,942 tons. With a powder factor of .56 pounds AN/FO per ton of produced rock one round will require approximately 1,650 pounds of explosives.

PROJECTED WORK CYCLE

CHARGING AND BLASTING

In projecting a 23 hole work cycle for a commercial operation certain factors were considered. Two of these factors are, the charging unit would be self-contained and the men assigned would perform only the charging and blasting functions.

PREPARE EQUIPMENT FOR WORKDAY - 20.00 MINUTES - LOAD EXPLOSIVE, APPROXIMATELY 7,000 LBS. - SERVICE EQUIPMENT

PROJECTED CHARGING AND BLASTING PROCEDURE

FOR A COMMERCIAL OPERATION

In order to attain maximum efficiency in the charging and blasting function the power unit will be a completely mobile, self-contained unit. It will be a diesel powered carrier equipped with an aerial platform capable of reaching any location on the face from one setup position. This would eliminate moving the truck during the charging sequence. The carrier will be equipped with a self-contained air injection system capable of injecting 150 pounds of explosives per minute and an explosives holding capacity of 7,000 pounds. This will be sufficient explosives for an eight hour shift and enough to load four rounds. These numbers are based on a round with dimensions of 35 feet wide by 40 feet high and a depth of 20 feet. At 14.925 cubic feet per ton of in-place oil shale rock one round will produce approximately 2,945 tons. With a powder factor of .50 pounds ANFO per ton of produced rock one round will require approximately 1,470 pounds of explosives.

PROJECTED WORK CYCLE

CHARGING AND BLASTING

In projecting a 23 hole work cycle for a commercial operation certain factors were considered. Two of these factors are, the charging unit would be self-contained and the man assigned would perform only the charging and blasting functions.

PREPARE EQUIPMENT FOR WORKDAY - 20.00 MINUTES - LOAD EXPLOSIVE, APPROXIMATELY 7,000 LBS. - SERVICE EQUIPMENT

	Average Time	Total Time 23 Hole Round
Move In	-	2.00 Minutes
Set Up	-	4.00 Minutes
Position and Reposition on Prospective Hole	.59	13.57 Minutes
Prepare Primer	.40	9.20 Minutes
Install Primer	.43	9.89 Minutes
Load Explosives in Hole	.48*	11.04 Minutes
Tie in Primer	.51	11.73 Minutes
Tie in Round	-	2.00 Minutes
Delays	-	8.00 Minutes
Prepare & Service Equipment For Work	Prorated	4.00 Minutes
Tear Down	-	4.00 Minutes
TOTAL		79.43 Minutes

*Based on an AN/FO injection rate of 150 pounds per minute.

PROJECTED WORK CYCLE

CHARGING AND BLASTING

Assume:

8 hour or 480 minute workday (collar to collar)

Allowances:

Travel to work place	10.00 Minutes
Lunch	30.00 Minutes *
Personal	15.00 Minutes
Supervision	10.00 Minutes
Return to Surface	15.00 Minutes
TOTAL	80.00 Minutes

Total Time	Average Time	
2.00 Minutes	-	Time in
4.00 Minutes	-	See in
13.57 Minutes	.59	Position and Reposition on Prospective Hole
9.20 Minutes	.40	Prepare Primer
9.89 Minutes	.43	Install Primer
11.04 Minutes	.48*	Load Explosives in Hole
11.73 Minutes	.51	The in Primer
2.00 Minutes	-	The in Round
8.00 Minutes	-	Delays
4.00 Minutes	Projected	Prepare & Service Equipment for Work
4.00 Minutes	-	Test Data
79.43 Minutes		TOTAL

*Based on an ANFO injection rate of 150 pounds per minute.

PROJECTED WORK CYCLE CHARGING AND BLASTING

Assumes:

8 hour or 480 minute workday (collar to collar)

Allowances:

Travel to work place	10.00 Minutes
Lunch	30.00 Minutes *
Personal	15.00 Minutes
Supervision	10.00 Minutes
Return to Surface	15.00 Minutes
TOTAL	80.00 Minutes

EXPLOSIVE HANDLING - POSITION AND REPOSITION

* Lunch Breakdown

5 Minutes to Lunch Room

Calculation to estimate true mean (μ) from sample data.

20 Minutes Lunch

5 Minutes to Return to Work

30 Minutes

1.75

480 - 80 = 400 minutes (possible productive work time)

$\frac{400}{79.43} = 5.03$ rounds charged and blasted per eight hour shift = 100.60 rounds/week

$$s(x) = \sqrt{\frac{sx^2 - \bar{x}^2}{n-1}} \quad \frac{\sum x^2}{n} - \frac{\bar{x}^2}{n} = \frac{249.60}{35} - \frac{1.75^2}{35} = 7.42$$

$$s(x) = \sqrt{\frac{249.60 - 1.75^2 (35)}{35 - 1}}$$

$$s(x) = \sqrt{\frac{249.60 - 1.75^2 (35)}{34}} = \sqrt{\frac{249.60 - 1.75^2 (35)}{34}} = \sqrt{7.42} = 1.22$$

$$S(X) = \frac{s(x)}{\sqrt{n}}$$

$$S(X) = \frac{1.22}{\sqrt{35}} = \frac{1.22}{7.42} = 0.16$$

\bar{X} @ 95% Confidence Level

$\bar{X} \pm Z \text{ at } 0.05 \cdot S(X)$

$\bar{X} = 1.75 \pm 2.005 (0.16)$

$\bar{X} = 1.75 \pm .32 \text{ minutes}$

* Lunch Breakdown

5 Minutes in Lunch Room

20 Minutes Lunch

5 Minutes to Return to Work

30 Minutes

480 - 80 = 400 minutes (possible productive work time)

400 = 2.03 rounds charged and blasted per eight hour shift = 100.60 rounds/shift

EXPLOSIVES LOADING - POSITION AND REPOSITION

Calculation to estimate true mean (M) from sample data.

$$\sum x = 96.25$$

$$N = 55$$

$$\bar{x} = 1.75$$

$$\sum x^2 = 248.60$$

$$S(x) = \sqrt{\frac{\sum x^2 - \bar{x} \sum x}{N-1}} \quad \rightsquigarrow \quad \frac{(\sum x_i)^2}{n} = \frac{\sum x_i}{n} \sum x_i = \bar{x} \sum x_i$$

$$S(x) = \sqrt{\frac{248.60 - 1.75 (96.25)}{55 - 1}}$$

$$S(x) = \sqrt{\frac{248.60 - 168.44}{54}} = \sqrt{\frac{80.16}{54}} = \sqrt{1.48} = 1.22$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{1.22}{\sqrt{55}} = \frac{1.22}{7.42} = 0.16$$

M @ 95% Confidence Level

$$M = \bar{x} \pm T_{0.05} S(\bar{x})$$

$$M = 1.75 \pm 2.005 (0.16)$$

$$M = 1.75 \pm .32 \text{ minutes}$$

EXPLOSIVES LOADING - POSITION AND REPOSITION

Calculation to estimate true mean (μ) from sample data.

$$\sum x = 96.25$$

$$N = 25$$

$$\bar{x} = 1.75$$

$$\sum x^2 = 248.60$$

$$s(x) = \sqrt{\frac{\sum x^2 - \frac{(\sum x)^2}{N}}{N-1}} = \sqrt{\frac{248.60 - \frac{(96.25)^2}{25}}{25-1}} = \sqrt{\frac{248.60 - 368.46875}{24}} = \sqrt{\frac{-119.86875}{24}} = \sqrt{-4.99453125} = 1.22$$

$$s(x) = \sqrt{\frac{\sum x^2 - \frac{(\sum x)^2}{N}}{N-1}} = \sqrt{\frac{248.60 - \frac{(96.25)^2}{25}}{25-1}} = \sqrt{\frac{248.60 - 368.46875}{24}} = \sqrt{\frac{-119.86875}{24}} = \sqrt{-4.99453125} = 1.22$$

$$s(x) = \sqrt{\frac{\sum x^2 - \frac{(\sum x)^2}{N}}{N-1}} = \sqrt{\frac{248.60 - \frac{(96.25)^2}{25}}{25-1}} = \sqrt{\frac{248.60 - 368.46875}{24}} = \sqrt{\frac{-119.86875}{24}} = \sqrt{-4.99453125} = 1.22$$

$$s(x) = \frac{s(x)}{\sqrt{N}} = \frac{1.22}{\sqrt{25}} = \frac{1.22}{5} = 0.244$$

$$s(x) = \frac{s(x)}{\sqrt{N}} = \frac{1.22}{\sqrt{25}} = \frac{1.22}{5} = 0.244$$

M @ 92% Confidence Level

$$M = \bar{x} \pm 0.05 s(x)$$

$$M = 1.75 \pm 2.005 (0.16)$$

$$M = 1.75 \pm .32 \text{ minutes}$$

EXPLOSIVES LOADING - PREPARING THE PRIMER

Calculation to estimate true mean (M) from sample data.

$$\sum x = 31.47$$

$$N = 46$$

$$\bar{x} = 0.69$$

$$\sum x^2 = 30.28$$

$$S(x) = \sqrt{\frac{\sum x^2 - \frac{(\sum x)^2}{N}}{N-1}}$$

$$S(x) = \sqrt{\frac{30.28 - \frac{(31.47)^2}{46}}{46 - 1}}$$

$$S(x) = \sqrt{\frac{30.28 - 21.71}{45}} = \sqrt{\frac{8.57}{45}} = \sqrt{0.19} = 0.44$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{0.44}{\sqrt{46}} = \frac{0.44}{6.78} = 0.06$$

M @ 95% Confidence Level

$$M = \bar{x} \pm T_{0.05} S(\bar{x})$$

$$M = 0.69 \pm 2.014 (0.06)$$

$$M = 0.69 \pm .12 \text{ minutes}$$

EXPLOSIVE LOADING - PREPARING THE PRIMER

Calculation to estimate true mean (μ) from sample data.

$$\begin{aligned} \bar{x} &= 31.47 \\ n &= 46 \\ \bar{s} &= 0.69 \\ s^2 &= 30.28 \end{aligned}$$

$$\begin{aligned} s(x) &= \sqrt{\frac{s^2}{n-1}} = \sqrt{\frac{30.28 - 0.69(31.47)}{46 - 1}} \\ s(x) &= \sqrt{\frac{8.27}{45}} = \sqrt{0.19} = 0.44 \end{aligned}$$

$$s(x) = \sqrt{\frac{30.28 - 21.71}{45}} = \sqrt{\frac{8.57}{45}} = \sqrt{0.19} = 0.44$$

$$\begin{aligned} s(x) &= \frac{s(x)}{\sqrt{n}} \\ s(x) &= \frac{0.44}{\sqrt{46}} = \frac{0.44}{6.78} = 0.06 \end{aligned}$$

M @ 95% Confidence Level

$$\begin{aligned} M &= \bar{x} \pm t(0.05) \cdot s(x) \\ M &= 31.47 \pm 2.014(0.06) \\ M &= 31.47 \pm 0.12 \text{ minutes} \end{aligned}$$

EXPLOSIVES LOADING - INSTALLING PRIMER

Calculation to estimate true mean (M) from sample data.

$$\bar{x} = 38.76$$

$$N = 57$$

$$\bar{x} = 0.68$$

$$\bar{x}^2 = 32.50$$

$$S(x) = \sqrt{\frac{\bar{x}^2 - \bar{x} \bar{x}}{N-1}}$$

$$S(x) = \sqrt{\frac{32.50 - .68 (38.76)}{57-1}}$$

$$S(x) = \sqrt{\frac{32.50 - 26.36}{56}} = \sqrt{\frac{6.14}{56}} = \sqrt{0.11} = 0.33$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{0.33}{\sqrt{57}} = \frac{0.33}{7.55} = 0.04$$

M @ 95% Confidence Level

$$M = \bar{x} \pm T_{0.05} S(\bar{x})$$

$$M = 0.68 \pm 2.003 (.04)$$

$$M = 0.68 \pm .08 \text{ minutes}$$

EXPLOSIVES LOADING - INSTALLING PRIMER

Calculation to estimate true mean (M) from sample data.

$$\bar{x} = 38.76$$

$$N = 27$$

$$\bar{x} = 0.68$$

$$s_x^2 = 32.50$$

$$s(x) = \sqrt{\frac{s_x^2 - \bar{x} \bar{x}}{N-1}}$$

$$s(x) = \sqrt{\frac{32.50 - .68(38.76)}{27-1}}$$

$$s(x) = \sqrt{\frac{32.50 - 26.36}{26}} = \sqrt{\frac{6.14}{26}} = \sqrt{0.23} = 0.33$$

$$s(x) = \frac{s(x)}{\sqrt{N}}$$

$$s(x) = \frac{0.33}{\sqrt{27}} = \frac{0.33}{5.22} = 0.04$$

M @ 95% Confidence Level

$$M = \bar{x} \pm t(0.025, 200)$$

$$M = 0.68 \pm 1.003(0.04)$$

$$M = 0.68 \pm 0.08 \text{ inches}$$

EXPLOSIVES LOADING - HOLE LOADING (PRILL)

Calculation to estimate true mean (M) from sample data.

$$\sum x = 154.47$$

$$N = 57$$

$$\bar{x} = 2.72$$

$$\sum x^2 = 466.88$$

$$S(x) = \sqrt{\frac{\sum x^2 - \bar{x} \sum x}{N-1}}$$

$$S(x) = \sqrt{\frac{466.88 - 2.72 (154.47)}{57-1}}$$

$$S(x) = \sqrt{\frac{466.88 - 420.15}{56}} = \sqrt{\frac{46.73}{56}} = \sqrt{.83} = 0.913$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{0.913}{\sqrt{57}} = \frac{0.913}{7.55} = 0.12$$

M @ 95% Confidence Level

$$M = \bar{x} \pm T_{0.05} S(\bar{x})$$

$$M = 2.72 \pm 2.003 (0.12)$$

$$M = 2.72 \pm 0.24 \text{ minutes}$$

EXPLOSIVES LOADING - HOLE LOADING (PRL)

Calculation to estimate true mean (Q) from sample data.

$$\begin{aligned} \bar{x} &= 124.47 \\ N &= 27 \\ \bar{x} &= 2.72 \\ \bar{x} &= 466.88 \end{aligned}$$

$$\begin{aligned} s(x) &= \sqrt{\frac{\sum x^2 - \frac{(\sum x)^2}{N}}{N-1}} \\ s(x) &= \sqrt{\frac{466.88 - 2.72(124.47)}{27-1}} \\ s(x) &= \sqrt{\frac{466.88 - 420.15}{26}} = \sqrt{\frac{46.73}{26}} = \sqrt{1.80} = 1.34 \end{aligned}$$

$$\begin{aligned} s(x) &= \frac{s(x)}{\sqrt{N}} \\ s(x) &= \frac{1.34}{\sqrt{27}} = \frac{1.34}{5.20} = 0.26 \end{aligned}$$

N @ 95% Confidence Level

$$M = \bar{x} \pm 10.05 s(x)$$

$$M = 2.72 \pm 2.003 (0.26)$$

$$M = 2.72 \pm 0.52 \text{ minutes}$$

EXPLOSIVES LOADING - TIE IN PRIMER

Calculation to estimate true mean (M) from sample data.

$$\sum x = 35.91$$

$$N = 49$$

$$\bar{x} = 0.63$$

$$\sum x^2 = 29.64$$

$$S(x) = \sqrt{\frac{\sum x^2 - \bar{x} \sum x}{N-1}}$$

$$S(x) = \sqrt{\frac{29.64 - (0.63) 35.91}{49 - 1}}$$

$$S(x) = \sqrt{\frac{29.64 - 22.62}{48}} = \sqrt{\frac{7.02}{48}} = \sqrt{0.15} = 0.38$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{0.38}{\sqrt{49}} = \frac{0.38}{7.00} = 0.05$$

M @ 95% Confidence Level

$$M = \bar{x} \pm T_{0.05} S(\bar{x})$$

$$M = 0.63 \pm 2.011 (0.05)$$

$$M = 0.63 \pm .10 \text{ minutes}$$

EXPLOSIVES HANDING - TIE IN PRIMER

Calculation to estimate true mean (μ) from sample data.

$$\sum x = 32.91$$

$$n = 48$$

$$\bar{x} = 0.63$$

$$\sum x^2 = 20.64$$

$$s(x) = \sqrt{\frac{\sum x^2 - \bar{x}^2 n}{n-1}}$$

$$s(x) = \sqrt{\frac{20.64 - (0.63)^2 48}{48 - 1}}$$

$$s(x) = \sqrt{\frac{20.64 - 22.62}{48}} = \sqrt{\frac{1.02}{48}} = \sqrt{0.12} = 0.38$$

$$s(\bar{x}) = \frac{s(x)}{\sqrt{n}}$$

$$s(\bar{x}) = \frac{0.38}{\sqrt{48}} = \frac{0.38}{7.00} = 0.05$$

M 95% Confidence Level

$$M = \bar{x} \pm 1.96 s(\bar{x})$$

$$M = 0.63 \pm 1.96 (0.05)$$

$$M = 0.63 \pm 10 \text{ minutes}$$

MAN/MACHINE TIME CHART

Actual Charging & Blasting - Anvil Points Mine

October 1975

<u>HOLE NO.</u>	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
	Get powder and set up equipment	1.09	51.76
1	Position	2.32	2.32
	Prepare primer	-	2.32
	Install primer	-	2.32
	Load explosives	4.15	6.47
	Tie in primer	.30	6.77
2	Reposition	2.00	8.77
	Prepare primer	1.00	9.77
	Install primer	.62	10.39
	Load explosives	1.80	12.19
	Tie in primer	1.00	13.19
	DELAY: string lead wire	6.00	19.19
3	Reposition	1.48	20.67
	Prepare primer	-	20.67
	Install primer	.55	21.22
	Load explosives	2.05	23.27
	Tie in primer	.95	24.22
4	Reposition	.92	25.14
	Prepare primer	.82	25.96
	Install primer	.44	26.40
	Load explosives	1.82	28.22
	Tie in primer	-	28.22
5	Reposition	1.27	29.49
	Fill prill pot	6.16	35.65
	Prepare primer	2.45	38.10
	Install primer	.65	38.75
	Load explosives	2.11	40.86
	Tie in primer	-	40.86
6	Reposition	.75	41.61
	Prepare primer	-	41.61
	Install primer	.62	42.23
	Load explosives	1.52	43.75
	Tie in primer	-	43.75
7	Reposition	3.62	47.37
	Prepare primer	-	47.37
	Install primer	.96	48.33
	Load explosives	2.34	50.67
	Tie in primer	-	50.67

MANUACHTER TIME CARD

Actual Operation & Blasting - North Point Mine

October 1975

HOLE NO.	ELEMENT	TIME	CUMULATIVE TIME
	Get powder and set up equipment		
1	Position	2.32	2.32
	Prepare primer	-	2.32
	Install primer	-	2.32
	Load explosives	4.12	6.44
	The in primer	.30	6.74
2	Reposition	2.00	8.74
	Prepare primer	1.00	9.74
	Install primer	.62	10.36
	Load explosives	1.80	12.16
	The in primer	1.00	13.16
	DELAY: string		
	Lead wire	6.00	19.16
3	Reposition	1.48	20.64
	Prepare primer	-	20.64
	Install primer	.22	21.22
	Load explosives	2.02	23.24
	The in primer	.92	24.22
4	Reposition	.92	25.14
	Prepare primer	.82	25.96
	Install primer	.44	26.40
	Load explosives	1.82	28.22
	The in primer	-	28.22
5	Reposition	1.22	29.44
	Fill drill pot	6.16	35.60
	Prepare primer	2.42	38.02
	Install primer	.62	38.64
	Load explosives	2.11	40.75
	The in primer	-	40.75
6	Reposition	.72	41.47
	Prepare primer	-	41.47
	Install primer	.62	42.09
	Load explosives	1.22	43.31
	The in primer	-	43.31
7	Reposition	3.62	46.93
	Prepare primer	-	46.93
	Install primer	.96	47.89
	Load explosives	2.34	50.23
	The in primer	-	50.23

MAN/MACHINE TIME CHARTActual Charging & Blasting - Anvil Points MineOctober 1975

<u>HOLE NO.</u>	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
8	Reposition	1.09	51.76
	Prepare primer	-	51.76
	Install primer	.69	52.45
	Load explosives	2.21	54.66
	Tie in primer	-	54.66
9	Reposition	.30	54.96
	Prepare primer	-	54.96
	Install primer	.42	55.38
	Load explosives	2.22	57.60
	Tie in primer	-	57.60
10	Reposition	.32	57.92
	Prepare primer	-	57.92
	Install primer	.46	58.38
	Load explosives	1.62	60.00
	Tie in primer	-	60.00
	Fill prill pot	3.81	63.81
11	Reposition	-	63.81
	Prepare primer	-	63.81
	Install primer	.84	64.65
	Load explosives	-	64.65
	Tie in primer	-	64.65
12	Reposition	4.66	69.31
	Prepare primer	-	69.31
	Install primer	-	69.31
	Load explosives	1.69	71.00
	Tie in primer	-	71.00
13	Reposition	1.14	72.14
	Prepare primer	-	72.14
	Install primer	1.23	73.37
	Load explosives	2.52	75.89
	Tie in primer	-	75.89
	Tie in round	-	75.89
	Remove equipment	18.31	94.20
	Get powder	42.00	136.20
	Set up equipment	16.72	152.92
14	Position	1.35	154.27
	Prepare primer	1.55	155.82
	Install primer	.45	156.27
	Load explosives	1.64	157.91
	Tie in primer	1.00	158.91

MANUALLY TIME CHART

Actual Counting & Blasting - Anvil Point Mine

October 1975

HOLE NO.	ELEMENT	TIME	CUMULATIVE TIME
8	Reposition	1.09	51.76
	Prepare primer	-	51.76
	Install primer	.69	52.45
	Load explosives	2.21	54.66
	Tie in primer	-	54.66
9	Reposition	.30	54.96
	Prepare primer	-	54.96
	Install primer	.43	55.39
	Load explosives	2.22	57.60
	Tie in primer	-	57.60
10	Reposition	.12	57.92
	Prepare primer	-	57.92
	Install primer	.46	58.38
	Load explosives	1.62	60.00
	Tie in primer	-	60.00
11	Fill drill pot	3.81	63.81
	Reposition	-	63.81
	Prepare primer	-	63.81
	Install primer	.84	64.65
	Load explosives	-	64.65
12	Tie in primer	-	64.65
	Reposition	4.66	69.31
	Prepare primer	-	69.31
	Install primer	-	69.31
	Load explosives	1.69	71.00
13	Tie in primer	-	71.00
	Reposition	1.14	72.14
	Prepare primer	-	72.14
	Install primer	1.23	73.37
	Load explosives	2.52	75.89
14	Tie in primer	-	75.89
	Tie in round	-	75.89
	Remove equipment	18.31	94.20
	Get powder	42.00	136.20
	Set up equipment	16.72	152.92
15	Position	1.35	154.27
	Prepare primer	1.52	155.82
	Install primer	.45	156.27
	Load explosives	1.64	157.91
	Tie in primer	1.00	158.91

MAN/MACHINE TIME CHARTActual Charging & Blasting - Anvil Points MineOctober 1975

<u>HOLE NO.</u>	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
15	Reposition	1.10	160.01
	Prepare primer	.79	160.80
	Install primer	.72	161.52
	Load explosives	2.06	163.58
	Tie in primer	.46	164.04
16	Reposition	.72	164.76
	Prepare primer	.23	164.99
	Install primer	.54	165.53
	Load explosives	2.02	167.55
	Tie in primer	.41	167.96
17	Reposition	1.01	168.97
	Prepare primer	.26	169.23
	Install primer	.36	169.59
	Load explosives	2.26	171.85
	Tie in primer	.28	172.13
	DELAY: Low air pressure	6.35	178.48
18	Reposition	1.30	179.78
	Prepare primer	-	179.78
	Install primer	.70	180.48
	Load explosives	3.02	183.50
	Tie in primer	.32	183.82
19	Reposition	.68	184.50
	Prepare primer	.50	185.00
	Install primer	.33	185.33
	Load explosives	3.52	188.85
	DELAY: no air	16.48	205.33
	Tie in primer	.26	205.59
	Fill prill pot	7.70	213.29
20	Reposition	2.00	215.29
	Prepare primer	1.50	216.79
	Install primer	.34	217.13
	Load explosives	7.26	224.39
	Tie in primer	.78	225.17
21	Reposition	-	225.17
	Prepare primer	.50	225.67
	Install primer	.51	226.18
	Load explosives	2.79	228.97
	Tie in primer	1.32	230.29

MAN/MACHINE TIME CHART

Actual Charting & Blasting - Anvil Point Mine

October 1975

HOLE NO.	ELEMENT	TIME	CUMULATIVE TIME
15	Reposition	1.10	160.01
	Prepare primer	.73	160.80
	Install primer	.73	161.52
	Load explosives	2.06	163.58
	The in primer	.46	164.04
16	Reposition	.73	164.76
	Prepare primer	.23	164.99
	Install primer	.24	165.23
	Load explosives	2.02	167.25
	The in primer	.41	167.66
17	Reposition	1.01	168.67
	Prepare primer	.26	168.93
	Install primer	.36	169.29
	Load explosives	2.26	171.55
	The in primer	.28	171.83
	DELAY: low air pressure	6.32	178.15
18	Reposition	1.30	179.45
	Prepare primer	-	179.78
	Install primer	.70	180.48
	Load explosives	2.02	182.50
	The in primer	.32	182.82
19	Reposition	.68	183.50
	Prepare primer	.20	183.70
	Install primer	.33	184.03
	Load explosives	2.52	186.55
	DELAY: no air	16.48	203.03
	The in primer	.26	203.29
	Fill drill pot	7.70	210.99
20	Reposition	2.00	212.99
	Prepare primer	1.50	214.49
	Install primer	.34	214.83
	Load explosives	7.26	222.09
	The in primer	.78	222.87
21	Reposition	-	222.87
	Prepare primer	.20	223.07
	Install primer	.21	223.28
	Load explosives	2.79	226.07
	The in primer	1.32	227.39

MAN/MACHINE TIME CHARTActual Charging & Blasting - Anvil Points MineOctober 1975

<u>HOLE NO.</u>	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
22	Reposition	.72	231.01
	Prepare primer	.33	231.34
	Install primer	.79	232.13
	Load explosives	2.19	234.32
	Tie in primer	.34	234.66
23	Reposition	1.09	235.75
	Prepare primer	-	235.75
	Install primer	.30	236.05
	Load explosives	2.50	238.55
	Tie in primer	.32	238.87
24	Reposition	2.31	241.18
	Prepare primer	.34	241.52
	Install primer	.55	242.07
	Fill prill pot	5.05	247.12
	Load explosives	2.30	249.42
	Tie in primer	.55	249.97
25	Reposition	1.62	251.59
	Prepare primer	.55	252.14
	Install primer	.55	252.69
	Load explosives	2.35	255.04
	Tie in primer	.42	255.46
26	Reposition	4.10	259.56
	Prepare primer	.76	260.32
	Install primer	1.53	261.85
	Load explosives	2.38	264.23
	Tie in primer	.34	264.57
27	Reposition	.80	265.37
	Prepare primer	.38	265.75
	Install primer	.65	266.40
	Load explosives	3.31	269.71
	Tie in primer	.32	270.03
28	Reposition	6.68	276.71
	Prepare primer	.39	277.10
	DELAY: blow out hole	4.95	282.05
	Install primer	.56	282.61
	Load explosives	2.18	284.79
	Tie in primer	.38	285.17

MANUACHINE THE GARD

Actual Charging & Blasting - Andri Pointe Mine

October 1975

HOLE NO.	ELEMENT	TIME	CUMULATIVE TIME
22	Reposition	.72	231.01
	Prepare primer	.33	231.34
	Install primer	.79	232.13
	Load explosives	2.19	234.32
	The in primer	.34	234.66
23	Reposition	1.09	235.75
	Prepare primer	-	235.75
	Install primer	.30	236.05
	Load explosives	2.50	238.55
	The in primer	.32	238.87
24	Reposition	2.31	241.18
	Prepare primer	.34	241.52
	Install primer	.55	242.07
	Fill drill pot	2.05	244.12
	Load explosives	2.30	246.42
	The in primer	.55	246.97
25	Reposition	1.62	251.59
	Prepare primer	.55	252.14
	Install primer	.55	252.69
	Load explosives	2.35	255.04
	The in primer	.42	255.46
26	Reposition	4.10	259.56
	Prepare primer	.76	260.32
	Install primer	1.23	261.85
	Load explosives	2.38	264.23
	The in primer	.34	264.57
27	Reposition	.80	265.37
	Prepare primer	.38	265.75
	Install primer	.65	266.40
	Load explosives	3.31	269.71
	The in primer	.32	270.03
28	Reposition	6.68	276.71
	Prepare primer	.79	277.50
	DELAY: blow out hole	4.95	282.45
	Install primer	.56	283.01
	Load explosives	2.18	285.19
	The in primer	.38	285.57

MAN/MACHINE TIME CHARTActual Charging & Blasting - Anvil Points MineOctober 1975

<u>HOLE NO.</u>	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
29	Reposition	2.70	287.87
	Prepare primer	1.00	288.87
	Install primer	1.00	289.87
	Load explosives	3.54	293.41
	Tie in primer	.39	293.80
30	Reposition	-	293.80
	Prepare primer	.52	294.32
	DELAY: blow out hole	4.00	298.32
	Install primer	.74	299.06
	Load explosives	2.53	301.59
	Tie in primer	.29	301.88
	DELAY: clean air screen	15.00	316.88
31	Reposition	3.29	320.17
	Prepare primer	.30	320.47
	DELAY: blow out hole	3.00	323.47
	Install primer	1.00	324.47
	Load explosives	2.28	326.75
	Tie in primer	.35	327.10
32	Reposition	5.08	332.18
	Prepare primer	.32	332.50
	Install primer	1.40	333.90
	Fill prill tank	5.35	339.25
	Load explosives	3.30	342.55
	Tie in primer	.41	342.96
33	Reposition	2.21	345.17
	Prepare primer	-	345.17
	Install primer	.35	345.52
	Load explosives	2.90	348.42
	Tie in primer	.39	348.81
34	Reposition	-	348.81
	Prepare primer	.49	349.30
	Install primer	.32	349.62
	Load explosive	2.44	352.06
	Tie in primer	.36	352.42
	Load explosives	3.06	355.48
	Tie in primer	1.20	356.68

MANUACHINE TIME CHART

Actual Charging & Blasting - Anvil Pointe Mine

October 1975

HOLE NO.	ELEMENT	TIME	CUMULATIVE TIME
29	Reposition	2.70	287.87
	Prepare primer	1.00	288.87
	Install primer	1.00	289.87
	Load explosives	3.54	293.41
	Set in primer	.39	293.80
30	Reposition	-	293.80
	Prepare primer	.52	294.32
	DELAY: blow out hole	4.00	298.32
	Install primer	.74	299.06
	Load explosives	2.53	301.59
	Set in primer	.39	301.88
	DELAY: clean air screen	12.00	316.88
31	Reposition	3.29	320.17
	Prepare primer	.30	320.47
	DELAY: blow out hole	3.00	323.47
	Install primer	1.00	324.47
	Load explosives	2.39	326.86
	Set in primer	.35	327.21
	Reposition	5.08	332.29
32	Prepare primer	.32	332.61
	Install primer	1.40	334.01
	Fill drill tank	2.32	336.33
	Load explosives	3.30	339.63
	Set in primer	.41	340.04
	Reposition	2.21	342.25
33	Prepare primer	-	342.25
	Install primer	.32	342.57
	Load explosives	2.90	345.47
	Set in primer	.39	345.86
	Reposition	-	345.86
34	Prepare primer	.49	346.35
	Install primer	.32	346.67
	Load explosive	2.44	349.11
	Set in primer	.36	349.47
	Reposition	-	349.47

MAN/MACHINE TIME CHART

Actual Charging & Blasting - Anvil Points Mine

October 1975

<u>HOLE NO.</u>	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
35	Reposition	1.94	354.36
	Prepare primer	1.20	355.56
	Install primer	.70	356.26
	Fill prill tank	5.01	361.27
	Load explosives	2.20	363.47
	Tie in primer	.39	363.86
	Tie in round	6.40	370.26
	Move out equipment	15.20	385.46
	Get powder	31.58	417.04
	Set up equipment	17.34	434.38
	Fill prill tank	6.68	441.06
36	Reposition	1.37	442.43
	Prepare primer	1.53	443.96
	Install primer	.48	444.44
	Load explosives	1.70	446.14
	Tie in primer	1.00	447.14
37	Reposition	1.11	448.25
	Prepare primer	.69	448.94
	Install primer	.75	449.69
	Load explosives	2.01	451.70
	Tie in primer	.49	452.19
38	Reposition	.70	452.89
	Prepare primer	.26	453.15
	Install primer	.58	453.73
	Load explosives	2.10	455.83
	Tie in primer	.35	456.18
39	Reposition	1.06	457.24
	Prepare primer	.23	457.47
	Install primer	.38	457.85
	Load explosives	2.30	460.15
	Tie in primer	.25	460.40
	DELAY: move truck	6.53	466.93
40	Reposition	1.33	468.26
	Prepare primer	.75	469.01
	Install primer	1.02	470.03
	Load explosives	5.06	475.09
	Tie in primer	1.20	476.29

MANUACHINE TIME CHART

Actual Charging & Blasting - Arvill Point Mine

October 1975

WELL NO.	EVENT	TIME	CUMULATIVE TIME
35	Reposition	1.04	354.38
	Prepare primer	1.30	355.68
	Install primer	1.70	357.38
	Fill drill tank	5.01	362.39
	Load explosives	2.30	364.69
	Toe in primer	.39	365.08
	Toe in round	8.40	373.48
	Move out equipment	12.30	385.78
	Get powder	31.28	417.06
	Set up equipment	17.34	434.40
	Fill drill tank	6.68	441.08
36	Reposition	1.37	442.45
	Prepare primer	1.23	443.68
	Install primer	.48	444.16
	Load explosives	1.70	445.86
	Toe in primer	1.00	446.86
37	Reposition	1.11	447.97
	Prepare primer	.89	448.86
	Install primer	.75	449.61
	Load explosives	2.01	451.62
	Toe in primer	.49	452.11
38	Reposition	.70	452.81
	Prepare primer	.26	453.07
	Install primer	.28	453.35
	Load explosives	2.10	455.45
	Toe in primer	.35	455.80
39	Reposition	1.06	456.86
	Prepare primer	.23	457.09
	Install primer	.38	457.47
	Load explosives	2.30	460.15
	Toe in primer	.25	460.40
	DETA: move truck	6.23	466.63
40	Reposition	1.33	467.96
	Prepare primer	.75	468.71
	Install primer	1.02	470.03
	Load explosives	2.06	472.09
	Toe in primer	1.20	473.29

MAN/MACHINE TIME CHARTActual Charging & Blasting - Anvil Points MineOctober 1975

<u>HOLE NO.</u>	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
41	Reposition	2.68	478.97
	Prepare primer	.34	479.31
	Install primer	.55	479.86
	Load explosives	4.05	483.91
	Tie in primer	.65	484.56
	Fill prill tank	5.10	489.66
42	Reposition	1.68	491.34
	Prepare primer	.34	491.68
	Install primer	.55	492.23
	Load explosives	2.32	494.55
	Tie in primer	.65	495.20
43	Reposition	1.32	496.52
	Prepare primer	.56	497.08
	Install primer	.53	497.61
	Load explosives	2.30	499.91
	Tie in primer	.46	500.37
44	Reposition	1.18	501.55
	Prepare primer	.67	502.22
	Install primer	1.35	503.57
	Load explosives	2.32	505.89
	Tie in primer	.31	506.20
45	Reposition	2.77	508.97
	Prepare primer	.32	509.29
	Install primer	.65	509.94
	Load explosives	3.13	513.07
	Tie in primer	.36	513.43
46	Reposition	1.78	515.21
	Prepare primer	.36	515.57
	Tie in primer	.39	519.33
47	Reposition	.65	519.98
	Prepare primer	.52	520.50
	Install primer	.38	520.88
	Load explosives	3.62	524.50
	Tie in primer	.29	524.79
	Install primer	.87	525.66
	Load explosives	3.05	528.71
	Tie in primer	1.18	529.89

MAN MACHINE TIME CHART
Actual Charging & Blasting - Anvil Pointe Mine
October 1975

<u>WELL NO.</u>	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
41	Reposition	2.68	478.97
	Prepare primer	.34	479.31
	Install primer	.22	479.86
	Load explosives	4.02	483.91
	Tie in primer	.62	484.56
	Fill drill tank	2.10	489.66
42	Reposition	1.68	491.34
	Prepare primer	.34	491.68
	Install primer	.22	492.23
	Load explosives	2.32	494.55
	Tie in primer	.62	495.20
43	Reposition	1.32	496.52
	Prepare primer	.26	497.08
	Install primer	.22	497.61
	Load explosives	2.30	499.91
	Tie in primer	.46	500.37
44	Reposition	1.18	501.55
	Prepare primer	.67	502.22
	Install primer	1.32	503.57
	Load explosives	2.32	505.89
	Tie in primer	.31	506.20
45	Reposition	2.77	508.97
	Prepare primer	.32	509.29
	Install primer	.62	509.94
	Load explosives	3.13	513.07
	Tie in primer	.36	513.43
46	Reposition	1.78	515.21
	Prepare primer	.36	515.57
	Tie in primer	.39	519.33
47	Reposition	.62	519.98
	Prepare primer	.22	520.50
	Install primer	.38	520.88
	Load explosives	3.62	524.50
	Tie in primer	.29	524.79

MAN/MACHINE TIME CHARTActual Charging & Blasting - Anvil Points MineOctober 1975

<u>HOLE NO.</u>	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
48	Reposition	1.48	526.27
	Prepare primer	.62	526.89
	Install primer	.38	527.27
	Load explosives	4.26	531.53
	Tie in primer	.87	532.40
49	Reposition	1.63	534.03
	Prepare primer	.52	534.55
	Install primer	.50	535.05
	Load explosives	2.70	537.75
	Tie in primer	1.35	539.10
50	Reposition	.71	539.81
	Prepare primer	.36	540.17
	Install primer	.74	540.91
	Load explosives	2.10	543.01
	Tie in primer	.36	543.37
51	Reposition	1.86	545.23
	Prepare primer	.33	545.56
	Install primer	.31	545.87
	Load explosives	2.56	548.43
	Tie in primer	.38	548.81
52	Reposition	2.53	551.34
	Prepare primer	1.10	552.44
	Install primer	1.41	553.85
	Load explosives	2.97	556.82
	Tie in primer	1.08	557.90
53	Reposition	1.02	558.92
	Prepare primer	.98	559.90
	Install primer	.54	560.44
	Load explosives	3.12	563.56
	Tie in primer	1.28	564.84
	Fill prill tank	7.65	572.49
	DELAY: move truck	8.27	580.76
54	Reposition	1.08	581.84
	Prepare primer	.89	582.73
	Install primer	.87	583.70
	Load explosives	3.05	586.75
	Tie in primer	1.18	587.93

MANAGEMENT TIME CHART
Actual Working & Blasting - Anvil Point Mine
October 1975

<u>HOLES NO.</u>	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
48	Reposition	1.48	526.27
	Prepare primer	.62	526.89
	Install primer	.38	527.27
	Load explosives	4.26	531.53
	The in primer	.87	532.40
49	Reposition	1.63	534.03
	Prepare primer	.52	534.55
	Install primer	.50	535.05
	Load explosives	2.70	537.75
	The in primer	1.35	539.10
50	Reposition	.71	539.81
	Prepare primer	.36	540.17
	Install primer	.74	540.91
	Load explosives	2.10	543.01
	The in primer	.36	543.37
51	Reposition	1.86	545.23
	Prepare primer	.33	545.56
	Install primer	.31	545.87
	Load explosives	2.56	548.43
	The in primer	.38	548.81
52	Reposition	2.23	551.04
	Prepare primer	1.10	552.14
	Install primer	1.41	553.55
	Load explosives	2.97	556.52
	The in primer	1.08	557.60
53	Reposition	1.02	558.62
	Prepare primer	.98	559.60
	Install primer	.54	560.14
	Load explosives	3.12	563.26
	The in primer	1.28	564.54
	Fill drill tank	7.62	572.16
	DELAY: move truck	8.27	580.43
54	Reposition	1.08	581.51
	Prepare primer	.89	582.40
	Install primer	.87	583.27
	Load explosives	3.02	586.29
	The in primer	1.18	587.47

MAN/MACHINE TIME CHART

Actual Charging & Blasting - Anvil Points Mine

October 1975

<u>HOLE NO.</u>	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
55	Reposition	2.85	590.78
	Prepare primer	1.05	591.83
	Install primer	1.00	592.83
	Load explosives	2.80	595.63
	Tie in primer	1.10	596.73
56	Reposition	1.60	598.33
	Prepare primer	.69	599.02
	Install primer	.76	599.78
	Load explosives	2.87	602.65
	Tie in primer	1.02	603.67
	DELAY: get one primadet - rats chewed through wires on one	27.88	631.55
57	Reposition	1.25	632.80
	Prepare primer	.98	633.78
	Install primer	.76	634.54
	Load explosives	3.20	637.74
	Tie in primer	1.07	638.81
58	Reposition	1.00	639.81
	Prepare primer	1.02	640.83
	Install primer	.85	641.68
	Load explosives	2.88	644.56
	Tie in primer	1.18	645.74
59	Reposition	.88	646.62
	Prepare primer	.65	647.27
	Install primer	.68	647.95
	Load explosives	2.84	650.79
	Tie in primer	.55	651.34
	Tie in round	7.61	658.95
	DELAY: dead battery	21.82	680.77
	Tear down - move out	18.91	699.68

MANUWRITE THE CARD

Actual Charges & Blasting - Andy Pointe Mine

October 1972

TIME	ELMENT	TIME	CUMULATIVE
590.78	Reposition	2.85	590.78
591.83	Prepare primer	1.05	591.83
592.83	Install primer	1.00	592.83
595.63	Load explosives	2.80	595.63
596.73	Tie in primer	1.10	596.73
598.33	Reposition	1.60	598.33
599.02	Prepare primer	.69	599.02
599.78	Install primer	.76	599.78
602.65	Load explosives	2.87	602.65
603.67	Tie in primer	1.02	603.67
	DELAY: feet one primer - cut - runs checked		
631.32	through wires on one	27.88	631.32
632.80	Reposition	1.25	632.80
633.78	Prepare primer	.98	633.78
634.54	Install primer	.76	634.54
637.74	Load explosives	3.20	637.74
638.81	Tie in primer	1.07	638.81
639.81	Reposition	1.00	639.81
640.83	Prepare primer	1.02	640.83
641.68	Install primer	.85	641.68
644.56	Load explosives	2.88	644.56
645.74	Tie in primer	1.18	645.74
646.62	Reposition	.88	646.62
647.27	Prepare primer	.65	647.27
647.92	Install primer	.68	647.92
650.79	Load explosives	2.84	650.79
651.34	Tie in primer	.55	651.34
658.92	Tie in round	7.61	658.92
680.77	DELAY: dead battery	21.82	680.77
692.68	Test down - move out	18.91	692.68

MAN/MACHINE TIME CHART

Actual Charging & Blasting - Anvil Points Mine

October 1975

SUMMARY SHEET

	<u>Total Time</u>	<u>Occurrences of Cycle Elements</u>	<u>Mean</u>	<u>Standard Deviation</u>	<u>%</u>
1. Position	96.25	55	1.75	1.24	71%
2. Prepare primer	31.94	46	0.6943	.44	64%
3. Install primer	38.74	57	0.68	.32	42%
4. Load explosives	155.04	57	2.72	.93	34%
5. Tie in primer	30.78	49	0.63	.35	57%
6. Fill prill pot	52.56	9	5.84	1.31	22%
7. Move in - move out	86.48	5	17.29	1.44	8%
8. Get powder	73.58	2	36.79	-	-
9. Tie in round	14.01	2	7.005	-	-
10. Delays	120.28	11			
11. Lunches	<u>96.55</u>	2	48.27*	-	-
	796.23				

*Lunches include five minutes travel to lunch and five minutes return to work.

MANUACHINE TIME CHART

Annual Charting & Blasting - Acvli Point Mine

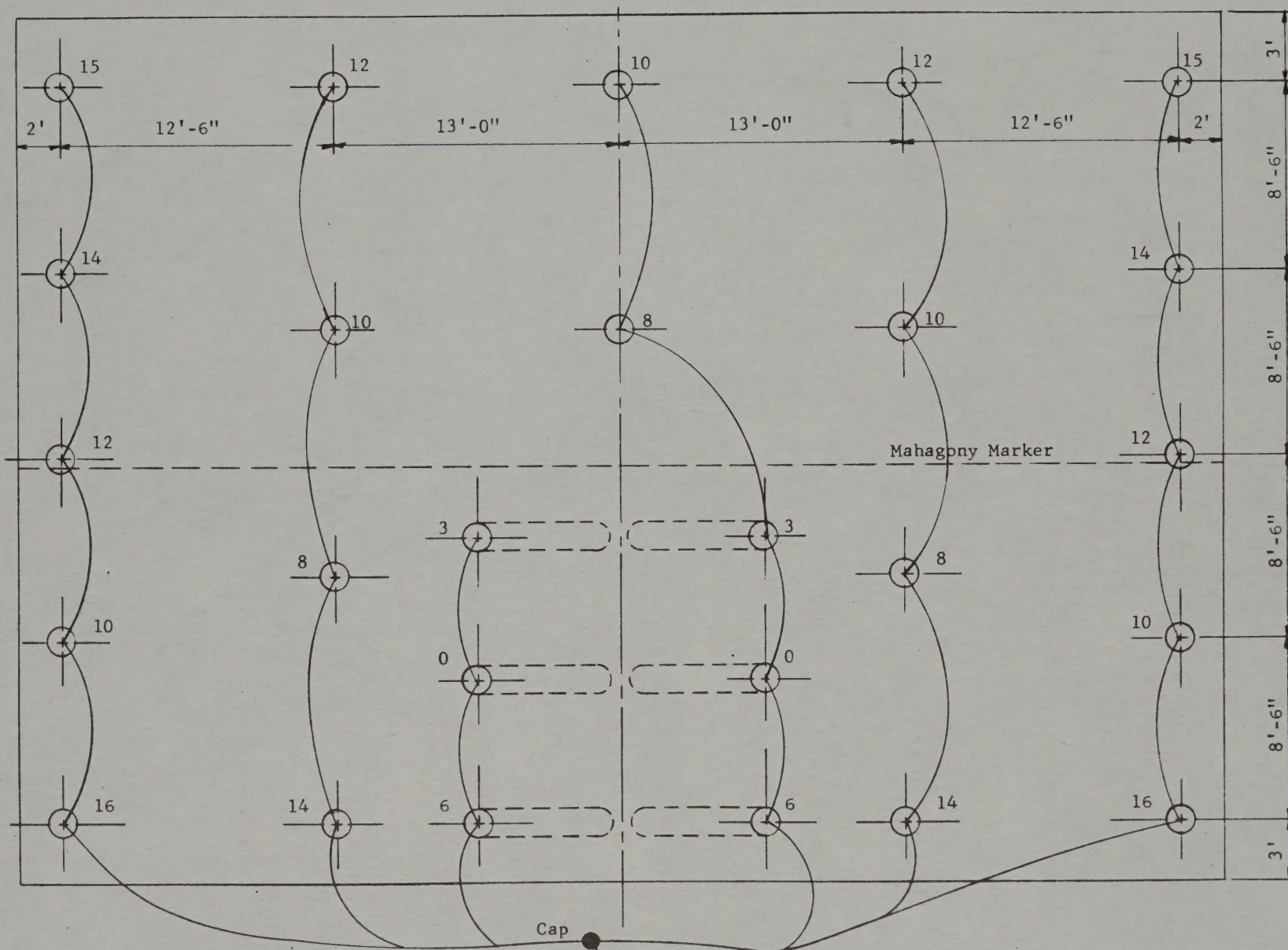
October 1972

SIMPLY SHEET

	Occurrences of Cycle Elements	Mean	Standard Deviation	%
1. Position	55	1.75	1.24	71%
2. Prepare primer	46	0.6943	.44	64%
3. Insert primer	57	0.68	.32	43%
4. Load explosives	57	2.72	.93	34%
5. Tie in primer	49	0.63	.35	57%
6. Fill drill pot	9	2.84	1.31	23%
7. Move in - move out	2	17.29	1.44	8%
8. Get powder	2	36.79	-	-
9. Tie in round	2	7.002	-	-
10. Delays	11			
11. Lunches	2	48.27*	-	-
				796.23

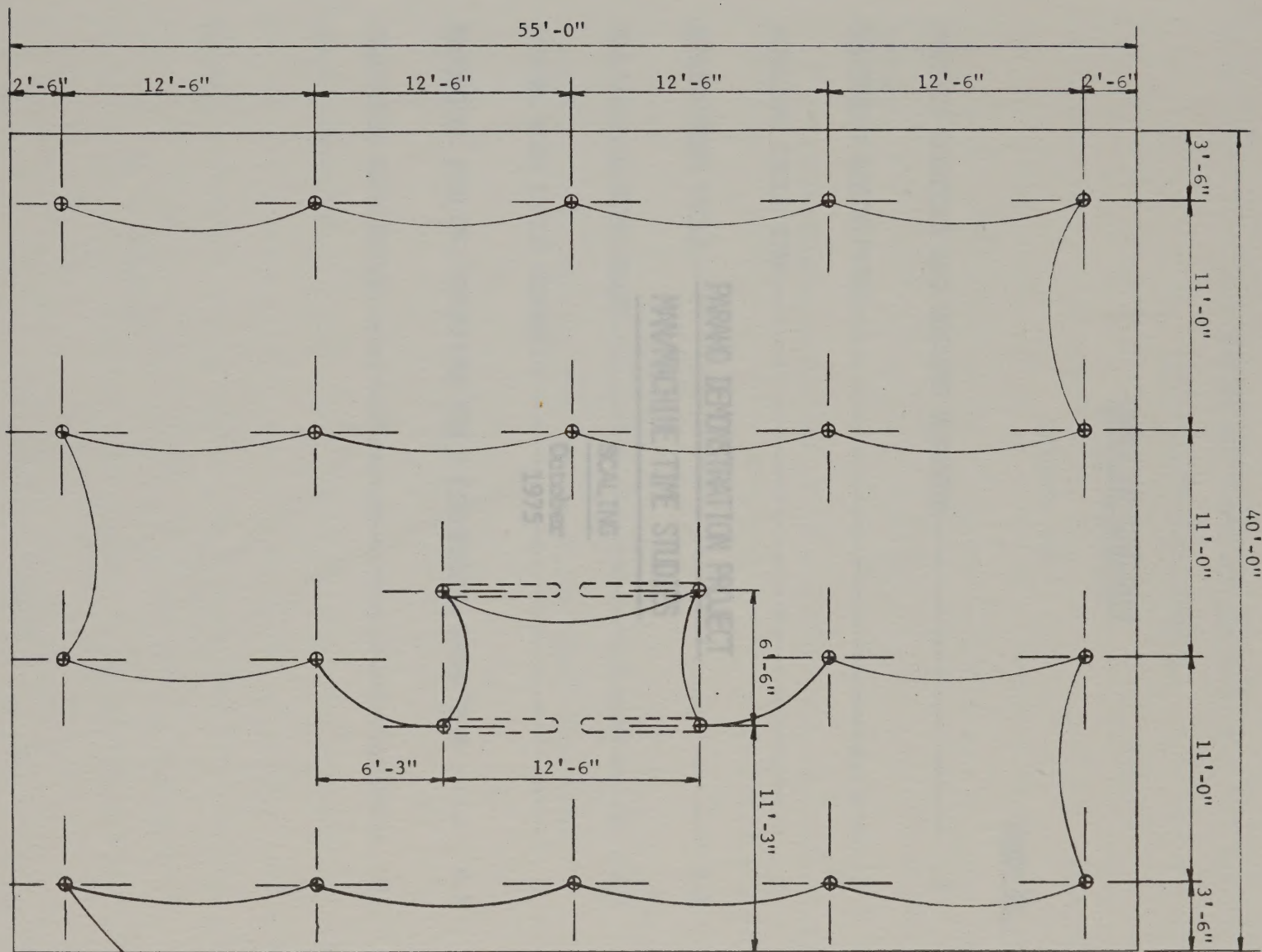
*Lunches include five minutes travel to lunch and five minutes return to work

FIGURE 1



EXPLOSIVES LOADING DELAY PATTERN FOR A 26 HOLE ROUND

WESTON BOND



PROJECTED EXPLOSIVES LOADING DELAY PATTERN FOR A 23 HOLE ROUND

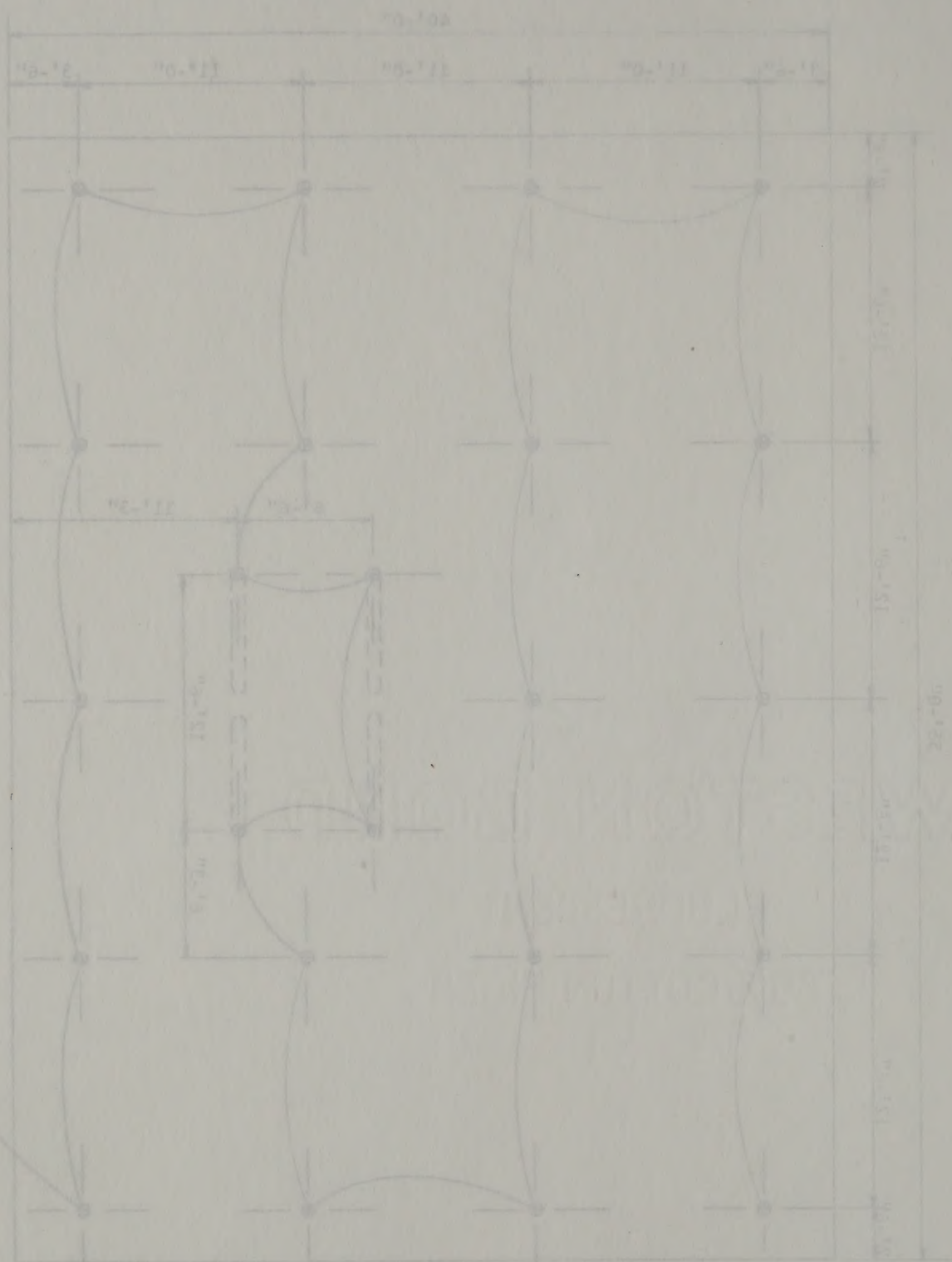


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W. W. Moulton

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PARAHO DEMONSTRATION PROJECT

MAN/MACHINE WORK STUDIES

Anvil Points Mine
Rifle, Colorado

October 1975

PROJECT:

Work Studies - Scaling

DESCRIPTION:

Work studies using elemental times were used to calculate a standard cycle time for the scaling of one twenty foot round.

PURPOSE:

Calculation of a scaling cycle time for a commercial size mining operation.

AUTHOR:

W. W. Moulton

PARADO DEMONSTRATION PROJECT

MAN/MACHINE WORK STUDIES

Anvil Pointe Mine
Rifle, Colorado

October 1972

PROJECT:

Work Studies - Sealing

DESCRIPTION:

Work studies using elemental times were used to calculate
a standard cycle time for the sealing of one twenty foot round.

PURPOSE:

Calculation of a sealing cycle time for a commercial size
winning operation.

AUTHOR:

W. W. Houston

PROJECT LOCATION AND SCALING FUNCTION

This industrial engineering project was performed at the Paraho Demonstration Project's Anvil Points Mine, near Rifle, Colorado. The mine utilizes room and pillar mining for the extraction of oil shale rock. Room dimensions are 55 feet wide and 40 feet high. A round advances twenty feet producing approximately 2,950 tons of oil shale rock. The scaling function follows the loading and hauling of this 2,950 tons of rock. Scaling of the face and ribs amounts to approximately 4,600 square feet of area in which seventy to one hundred tons of oil shale rock are produced. Some hand scaling is required in the present operation as the scaling machine will only reach to within three feet of the roof. Even with a four foot boom extension the maximum reach is thirty-seven feet.

EQUIPMENT DESCRIPTION

A Gradall 660 rubber-tired, hydraulic excavator with a telescoping boom equipped with a ripper tooth is used for scaling. The unit is diesel powered with a dry oxy-catalyst scrubber on the exhaust.

Cleanup equipment consists of a Hough 560 Pay Loader equipped with a 6.5 yard bucket and two fifty ton International Harvester Pay Hauler trucks. These are the main loading and hauling components.

CONDITIONS - AREA TO BE SCALED:

STANDARD CYCLE TIME

Floor - Irregular

The scaling function takes place following the loading

Right Rib - 30' wide x 40' high - normal after blast

Left Rib - 30' wide x 40' high - normal after blast

PROJECT LOCATION AND SCALING FUNCTION

This industrial engineering project was performed at the Paraho Demonstration Project's Avon Point Mine, near Rifle, Colorado. The mine utilizes room and pillar mining for the extraction of oil shale rock. Room dimensions are 55 feet wide and 40 feet high. A round advances twenty feet producing approximately 2,950 tons of oil shale rock. The scaling function follows the loading and hauling of this 2,950 tons of rock. Scaling of the face and ribs amounts to approximately 4,600 square feet of area in which seventy to one hundred tons of oil shale rock are produced. Some hand scaling is required in the present operation as the scaling machine will only reach to within three feet of the roof. Even with a four foot boom extension the machine reach is thirty-seven feet.

EQUIPMENT DESCRIPTION

A Grapple 660 ripper-circled, hydraulic excavator with a telescoping boom equipped with a ripper tooth is used for scaling. The unit is diesel powered with a dry oxy-catalyst scrubber on the exhaust. Cleanup equipment consists of a Hough 560 Pay Loader equipped with a 6.5 yard bucket and two fifty ton International Harvester Pay Hauler trucks. These are the main loading and hauling components.

STANDARD CYCLE TIME

The scaling function takes place following the loading

and hauling function. Standard cycle time is the computation of the total time required to scale the area exposed by a twenty foot round. Total time is the summation of elemental times derived from the timing of cycle elements. Cycle elements for scaling are as follows:

STANDARD CYCLE TIME:

- 1) Spot and respot scaler at various locations in drift
- 2) Scale (time duration for a given area)

The above cycle elements form a part of the total work cycle. The other parts of the total work cycle are delays and the hand scaling of the upper three feet of the face and ribs in each round. Timewise, the hand scaling element forms the major part of the total work cycle.

The man/machine time chart, page 5, is a step by step breakdown of cycle element times with a cumulative time summation. This chart is followed by a summary which shows total times, tons of rock scaled per minute, square feet scaled per minute and the number of rounds scalable per day.

ACTUAL WORK CYCLE

Scaling - 1 operator - 1 scaling machine

CONDITIONS - AREA TO BE SCALED:

Floor - Irregular

Face - 55' wide x 40' high - normal after blast

Right Rib - 30' wide x 40' high - normal after blast

Left Rib - 30' wide x 40' high - normal after blast

and hauling function. Standard cycle time is the comparison of the total time required to scale the area exposed by a twenty foot round. Total time is the summation of elemental times derived from the timing of cycle elements. Cycle elements for scaling are as follows:

STANDARD CYCLE TIME

- 1) Spot and re-spot scaler at various locations in drift
- 2) Scale (time duration for a given area)

The above cycle elements form a part of the total work cycle. The other parts of the total work cycle are delays and the hand scaling of the upper three feet of the face and ribs in each round. Likewise, the hand scaling element forms the major part of the total work cycle.

The man/machine time chart, page 5, is a step by step breakdown of cycle element times with a cumulative time summation. This chart is followed by a summary which shows total times, tons of rock scaled per minute, square feet scaled per minute and the number of rounds scalable per day.

ACTUAL WORK CYCLE

Scalier - 1 operator - 1 scaling machine

CONDITIONS - AREA TO BE SCALED

Floor - Irregular
 Face - 55' wide x 40' high - normal after blast
 Right Rib - 30' wide x 40' high - normal after blast
 Left Rib - 30' wide x 40' high - normal after blast

ACTUAL WORK CYCLE

POSSIBLE PRODUCTIVE WORK TIME: required - 4 hours - 2 min

(Assume 100% utilization of available time)

Allowances:

Travel to Work	30 Minutes
Travel to Lunch	5 Minutes
Lunch	30 Minutes *
Return to Work Place	5 Minutes
Personal	15 Minutes
Supervision	15 Minutes
Travel from Mine	30 Minutes
	100 Minutes

* Not Paid and Not Included in Total

Total Work Day - 8 hours or 480 minutes = 480 - 100 = 380
(possible productive work time)

Actual Work Times - Starting Time	11:20)	
Go to Lunch	12:00)	40 Minutes
Return to Work	12:45)	
Finishing Time	2:44)	119 Minutes
			159 Minutes

POSSIBLE PRODUCTIVE WORK TIME

(Assume 100% utilization of available time)

Allowances:

Travel to Work	30 Minutes
Travel to Lunch	5 Minutes
Lunch	30 Minutes *
Return to Work Place	5 Minutes
Personal	15 Minutes
Supervision	15 Minutes
Travel from Mine	<u>30 Minutes</u>
	100 Minutes

* Not Paid and Not Included in Total

Total Work Day - 8 hours or 480 minutes = 480 - 100 = 380
(possible productive work time)

Actual Work Times - Starting Time	11:20	}	40 Minutes
Go to Lunch	12:00		
Return to Work	12:45	}	<u>115 Minutes</u>
Finishing Time	2:00		
			155 Minutes

ACTUAL WORK CYCLE

Hand Scaling Required - 4 hours - 2 men

Actual Time: 8:25 A.M. to 12:25 P.M. (Done the day after mechanical scaling was done)

ACTUAL LUNCH:

5 Minutes to Lunch

35 Minutes Lunch (30 Minutes Not Paid)

5 Minutes to Return to Work

MAN/MACHINE TIME CHART

<u>Cycle Element</u>	<u>Time</u>	<u>Cumulative Time</u>	<u>Distance Traveled</u>
Move into face	5.49	5.49	630 feet
Set up on right rib	.44	5.93	
Scaling	17.62	23.55	
Respot at right rib	.28	23.83	
Scaling	2.22	26.05	
Respot at right rib	.35	26.40	
Scaling	5.52	31.92	
Respot to left rib	.82	32.74	
Scaling	4.42	37.16	
Respot to center face	.76	37.92	
Delay: inspect face	3.92	41.84	
Delay: inspect boom	2.24	44.08	
Delay: wait for dust to clear	2.64	46.72	
Scaling	21.73	68.45	
Respot to right face	.22	68.67	
Scaling	8.20	76.87	
Respot to left rib	.98	77.85	
Scaling	17.85	95.70	
Delay: inspect boom	1.37	97.07	
Respot to left rib	.48	97.55	
Scaling	7.64	105.19	
Respot to left rib	1.04	106.23	
Scaling	8.62	114.85	
Respot to left rib	2.46	117.31	
Scaling	9.82	127.13	
Move out of face	5.32	132.45	585 feet
Clean up muck	26.55	159.00	
Lunch	45.00	204.00	
Hand scaling	240.00	444.00	

ACTUAL WORK CYCLE

Hand Sealing Required - 4 hours - 2 men

Actual Time: 8:25 A.M. to 12:25 P.M. (Time the day after mechanical sealing was done)

ACTUAL LUNCH

5 Minutes to Lunch

35 Minutes Lunch (30 Minutes Not Paid)

5 Minutes to Return to Work

MANUACHINE THE CHART

Distance Traveled	Cumulative Time	Time	Cycle Element
630 feet	2.49	2.49	Move into face
	2.93	.44	Set up on right rib
	23.22	17.62	Sealing
	23.83	.28	Respond at right rib
	26.02	2.22	Sealing
	28.40	.38	Respond at right rib
	31.92	2.52	Sealing
	32.74	.82	Respond to left rib
	37.16	4.42	Sealing
	37.92	.76	Respond to center face
	41.84	3.92	Delay: inspect face
	44.08	2.24	Delay: inspect boom
	46.72	2.64	Delay: wait for dust to clear
	68.43	21.73	Sealing
	68.67	.22	Respond to right face
	76.87	8.20	Sealing
	79.82	.98	Respond to left rib
	92.70	12.82	Sealing
	97.07	4.37	Delay: inspect boom
	97.22	.15	Respond to left rib
	102.19	4.97	Sealing
	106.23	4.04	Respond to left rib
	114.82	8.59	Sealing
	117.31	2.49	Respond to left rib
	127.13	9.82	Sealing
	132.42	5.29	Move out of face
	138.00	5.58	Clean up truck
	204.00	66.00	Lunch
282 feet	444.00	240.00	Hand sealing

ACTUAL WORK CYCLE

SUMMARY

TOTAL TIME - MECHANICAL SCALING 159 Minutes
TOTAL TIME - HAND SCALING 240 Minutes
TOTAL TIME 399 Minutes

Mechanically scaled approximately 72 tons, 75 tons with hand scaling.

$$\frac{72}{159.00} = .452 \text{ tons/minute scaled mechanically}$$

$$\frac{75}{399.00} = .188 \text{ tons/minute scaled (includes hand scaling)}$$

$$\frac{4600}{399.00} = 28.93 \text{ square feet/minute scaled mechanically}$$

$$\frac{380 \text{ minutes/day (PPWT*)}}{159.00} = 2.39 \text{ rounds scaled/day mechanically}$$

$$\frac{380 \text{ minutes/day (PPWT*)}}{399.00} = .952 \text{ rounds scaled/day (includes hand scaling)}$$

*Possible Productive Work Time

PROJECTED SCALING REQUIREMENTS FOR A COMMERCIAL OPERATION

In order to attain maximum efficiency in the scaling function in a commercial size operation a scaling machine will have to meet the following parameters:

1. Material
 - a. Oil Shale (Marlstone)
 - b. 75-80 lbs./ft.
 - c. Loose slabs up to 2 tons
 - d. Material breaks with conchoidal fractures, has very sharp edges, is dusty, free flowing and slightly alkaline

ACTUAL WORK CYCLE

SUMMARY

TOTAL TIME - MECHANICAL SCALING	159 Minutes
TOTAL TIME - HAND SCALING	340 Minutes
TOTAL TIME	399 Minutes

Mechanically scaled approximately 75 tons, 75 tons with hand scaling.

$$\frac{75}{159.00} = .472 \text{ tons/minute scaled mechanically}$$

$$\frac{75}{399.00} = .188 \text{ tons/minute scaled (includes hand scaling)}$$

$$\frac{4600}{399.00} = 11.53 \text{ square feet/minute scaled mechanically}$$

$$\frac{380 \text{ minutes/day (PWT)}}{159.00} = 2.39 \text{ rounds scaled/day mechanically}$$

$$\frac{380 \text{ minutes/day (PWT)}}{399.00} = .952 \text{ rounds scaled/day (includes hand scaling)}$$

*Possible Productive Work Time

PROJECTED SCALING REQUIREMENTS FOR A COMMERCIAL OPERATION

In order to obtain maximum efficiency in the scaling function

in a commercial size operation a scaling machine will have to meet

the following parameters:

1. Material
 - a. Oil Shale (Gardiner)
 - b. 75-80 lbs. V/L
 - c. Layer about 1 to 2 tons
 - d. Material breaks with controlled fractures, has very sharp edges, is hard, free flaking and slightly silty

2. Scaling Concept

a. Upper level heading

- 1) right rib 30 ft. wide X 35 ft. high
- 2) face 55 ft. wide X 35 ft. high
- 3) left rib 30 ft. wide X 35 ft. high

b. Lower level bench

- 1) right rib 30 ft. wide X 45 ft. high
- 2) left rib 30 ft. wide X 45 ft. high

c. One cut heading (if possible)

- 1) right rib 30 ft. wide X 55 to 60 ft. high
- 2) face 55 ft. wide X 55 to 60 ft. high
- 3) left rib 30 ft. wide X 55 to 60 ft. high

d. Average cycle generates 80 to 100 tons of scaled rock

e. Scaling would be done between mucking and roof bolting- 3 shifts per day - 7 days per week

f. Trammig distance of 300 feet between scaling areas

3. Design Factors

a. Operator requirements

- 1) one man operation from common scaling - trammig cab
- 2) low operator fatigue
- 3) operator safety from falling - ricocheting rock and isolation from dust
- 4) operator be elevated for good visibility of full scaling height
- 5) control levers have "deadman" self-centering
- 6) sufficient illumination of scaling surface

NOTE: Infrared scanners are being studied by the U. S. Bureau of Mines for detection of loose slabs to facilitate more efficient scaling.

b. Equipment requirements

- 1) scaler undercarriage maintain a safe distance from the face
- 2) scaling device be a single ripper or scaling tooth with a raking or prying action
- 3) anticipation of 200+ H.P. integral unit
- 4) stable boom and undercarriage, to withstand severe shock from a sudden release of energy as rock comes free
- 5) do effective scaling
- 6) high degree of mobility
- 7) acceptable equipment working availability
- 8) ability to scale over the side of the carrier to cut down repositioning time
- 9) productivity
- 10) good availability of spare parts
- 11) maintain low operating and maintenance cost
- 12) meets Federal regulations for underground safety and emission
- 13) maximum equipment life possible for low unit replacement in a 20 year or more operation

2. Sealing Concept

- a. Upper level heading
 - 1) right rib 30 ft. wide X 35 ft. high
 - 2) face 55 ft. wide X 35 ft. high
 - 3) left rib 30 ft. wide X 35 ft. high
- b. Lower level bench
 - 1) right rib 30 ft. wide X 45 ft. high
 - 2) left rib 30 ft. wide X 45 ft. high
- c. One cut heading (if possible)
 - 1) right rib 30 ft. wide X 55 to 60 ft. high
 - 2) face 55 ft. wide X 55 to 60 ft. high
 - 3) left rib 30 ft. wide X 55 to 60 ft. high
- d. Average cycle generates 80 to 100 tons of scaled rock
- e. Scaling would be done between mucking and roof bolting - 2 shifts per day - 7 days per week
- f. Trimming distance of 300 feet between scaling areas

3. Design Factors

- a. Operator requirements
 - 1) one man operation from common scaling - trimming cap
 - 2) low operator fatigue
 - 3) operator safety from falling - ricocheting rock and falling from face
 - 4) operator be elevated for good visibility of full scaling height
 - 5) control levers have "deadman" self-centering
 - 6) sufficient illumination of scaling surface
- b. Equipment requirements
 - 1) scaler undercarriage maintain a safe distance from the face
 - 2) scaling device be a single tipper or scaling tooth with a raking or prying action
 - 3) anticipation of 200+ H.P. integral unit
 - 4) stable boom and undercarriage, to withstand severe shock from a sudden release of energy as rock comes free
 - 5) do effective scaling
 - 6) high degree of mobility
 - 7) acceptable equipment working availability
 - 8) ability to scale over the side of the carrier to cut down repositioning time
 - 9) productivity
 - 10) good availability of spare parts
 - 11) maintain low operating and maintenance cost
 - 12) meet Federal regulations for underground safety and emission
 - 13) maximum equipment life possible for low unit replacement in a 20 year or more operation

PROJECTED WORK CYCLE

A work cycle in a commercial size operation will require little or no hand scaling as the scaler will be able to reach all points in a recently blasted area. A projected work cycle time for a commercial scaling operation based on the previous scaler requirements is as follows:

- 1) Scale a standard size heading (approximately 4,600 square feet) in approximately 83.63 minutes
- 2) At 55 square feet scaled per minute
- 3) And based on 100 tons of scaled rock per round this equals .0217 tons of rock scaled per square foot.

ASSUME:

8 hour or 480 minute work day (collar to collar)

Allowances:

Travel to work place	10 Minutes
Lunch	30 Minutes *
Personal	15 Minutes
Supervision	10 Minutes
Return to Surface	<u>15 Minutes</u>
	80 Minutes

* Lunch Breakdown

5 minutes to lunch room
20 minutes to lunch
5 minutes to return to work

480 - 80 = 400 minutes (possible productive work time)

$$\frac{400}{83.63} = 4.783 \text{ rounds scaled per 8 hour shift}$$

= 95.66 rounds scaled per week

PROJECTED WORK CYCLE

A work cycle in a commercial size operation will require little

or no hand scaling as the scaler will be able to reach all points in

a recently blasted area. A projected work cycle time for a commercial

scaling operation based on the previous scaler requirements is as follows:

- 1) Scale a standard size heading (approximately 4,800 square feet) in approximately 83.63 minutes
- 2) At 55 square feet scaled per minute
- 3) And based on 100 tons of scaled rock per round this equals .0217 tons of rock scaled per square foot

ASSUME:

8 hour or 480 minute work day (collar to collar)

Allowances:

Travel to work place	10 Minutes
Lunch	30 Minutes *
Personal	15 Minutes
Supervision	10 Minutes
Return to Surface	15 Minutes
	<u>80 Minutes</u>

* Lunch Breakdown

5 minutes to lunch room
20 minutes to lunch
5 minutes to return to work

480 - 80 = 400 minutes (possible productive work time)

$$\frac{400}{55} = 7.27 \text{ rounds scaled per 8 hour shift}$$

= 92.66 rounds scaled per week

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MAN/MACHINE WORK STUDIES

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PARAHO DEMONSTRATION PROJECT

MAN/MACHINE WORK STUDIES

Anvil Points Mine
Rifle, Colorado

October 1975

PROJECT:

Work Studies - Roof Bolting

DESCRIPTION:

Work studies utilizing a break out of elemental times were used to calculate a standard cycle time for roof bolting one 20-foot round.

PURPOSE:

Calculate a roof bolting cycle for a commercial size mining operation.

AUTHOR:

W. W. Moulton

Item		Size	Remarks
Bits	Tholen	1-5/8" and 1-3/4"	Tungsten/Carbide Rotary- Perforation Bit
Steel	Gardner-Denver	1-1/8" round steel with 1-1/8" Hex Shank	
Roof Bolts	Colorado Fuel & Iron	3/4" x 6', 7', & 10'	10' bolts used along ribs
Roof Bolt Anchor	Patten	B-3 Patten Expansion Shell	
Plates	Colorado Fuel & Iron	6" x 6" x 3/16"	

FAVARD DEMONSTRATION PROJECT

MAN/MACHINE WORK STUDIES

Avanti Potomac Mine
Rifle, Colorado

October 1975

PROJECT:

Work Studies - Roof Bolting

DESCRIPTION:

Work studies utilizing a break out of elemental times were used to calculate a standard cycle time for roof bolting one 20-foot round.

PURPOSE:

Calculate a roof bolting cycle for a commercial size mining operation.

AUTHOR:

W. W. Martin

PROJECT LOCATION AND ROOF BOLT FUNCTION

This industrial engineering project was performed at the Paraho Demonstration Project's Anvil Points Mine, near Rifle, Colorado. The mine utilizes room and pillar mining for the extraction of oil shale rock. Room dimensions are 55 feet wide and 40 feet high. The roof is a natural parting plane approximately 20 feet above the Mahogany Marker.

It is felt roof bolting is necessary to create and insure a continuous and more competent roof beam.

EQUIPMENT DESCRIPTION

Roof bolting is performed by an aerial crane mounted on a rubber-tired, diesel powered carrier (Figure 1). Drilling is accomplished by a Gardner-Denver D-93 HR drill equipped with screw feed and hydraulic rotation. This drill is mounted on the crane platform.

Table I below indicates the type and manufacturer of the bits, steel, roof bolts and other accessories used in the roof bolting sequence.

TABLE I

<u>Item</u>	<u>Manufacturer</u>	<u>Size</u>	<u>Remarks</u>
Bits	Timken	1-5/8" and 1-3/4"	Tungsten/Carbide Rotary-Percussion Bit
Steel	Gardner-Denver	1-1/8" round steel with 1-1/8" Hex Shank	
Roof Bolts	Colorado Fuel & Iron	3/4" x 6', 7', & 10'	10' bolts used along ribs
Roof Bolt Anchor	Patten	D-3 Patten Expansion Shell	
Plates	Colorado Fuel & Iron	6" x 6" x 3/16"	

PROJECT LOCATION AND ROOF BOLTING

This industrial engineering project was performed at the Paraho Demonstration Project's Newell Point Mine, near Rifle, Colorado. The mine utilizes room and pillar mining for the extraction of oil shale rock. Room dimensions are 35 feet wide and 40 feet high. The roof is a natural parting plane approximately 20 feet above the Mahogany Marker. It is felt roof bolting is necessary to create and insure a continuous and more consistent roof beam.

EQUIPMENT DESCRIPTION

Roof bolting is performed by an aerial crane mounted on a ribber-cried, diesel powered carrier (Figure 1). Drilling is accomplished by a Gardner-Denver D-33 bit drill equipped with screw feed and hydraulic rotation. This drill is mounted on the crane platform. Table I below indicates the type and manufacturer of the bits, steel, roof bolts and other accessories used in the roof bolting sequence.

TABLE I

Item	Manufacturer	Size	Remarks
Bits	Tishen	1-5/8" and 1-3/4"	Targsten/Cathala Rotary Percussion Bit
Steel	Gardner-Denver	1-1/8" round steel with 1-1/8" Hex Shank	
Roof Bolts	Colorado Fuel & Iron	3/4" x 6', 7', & 10'	10' bolts used along rd
Roof Bolt Anchor	Patterson	D-3 Pattern Expansion Drill	
Plates	Colorado Fuel & Iron	6" x 6" x 3/16"	

STANDARD CYCLE TIME

The roof bolting cycle takes place after a heading has been blasted and mucked.

Standard cycle time is the computation of the total time required to bolt the back exposed by a 20 foot round. Total time is the summation of the elemental times derived from the timing of the cycle elements. Cycle elements for roof bolting are as follows:

1. Move in, set up, tear down and move out;
2. Locate and relocate on prospective hole;
3. Collaring the hole;
4. Drilling the hole;
5. Retracting the drill;
6. Inserting the bolt;
7. Anchoring the bolt.

The above cycle elements form the major part of the total work cycle. The other part of the total work cycle is made up of various delays. These delays are noted in the man/machine charts where they occurred in the bolting sequence.

Standard industrial engineering procedures used in this analysis involve calculation of mean times, standard deviation and percent standard deviation. In order to determine if a sufficient number of element cycles were recorded to allow a confidence level of 95 percent, each element cycle was analyzed using the "t" test. This calculation is included on pages 9 to 15.

The man/machine time chart, pages 15 to 23, is a step by step breakdown of cycle element times with a cumulative time summation.

STANDARD CYCLE TIME

The roof bolting cycle takes place after a heading has been

blasted and mucked.

Standard cycle time is the computation of the total time

required to bolt the back exposed by a 20 foot round. Total time is the

sum of the elemental times derived from the timing of the cycle

elements. Cycle elements for roof bolting are as follows:

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cycle. The other part of the total work cycle is made up of various delays.

These delays are noted in the man-machine charts where they occurred in

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Standard industrial engineering procedures used in this analysis

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deviation. In order to determine if a sufficient number of element cycles

were recorded to allow a confidence level of 95 percent, each element

cycle was analyzed using the "t" test. This calculation is included

on pages 9 to 15.

The man-machine time chart, pages 15 to 23, is a step by step

breakdown of cycle element times with a cumulative time summation.

This chart is followed by a summary sheet which shows the total times, means, standard deviations and percent standard deviations for each cycle element.

ACTUAL WORK CYCLE

Roof Bolting - 1 operator - 1 drill

CONDITIONS:

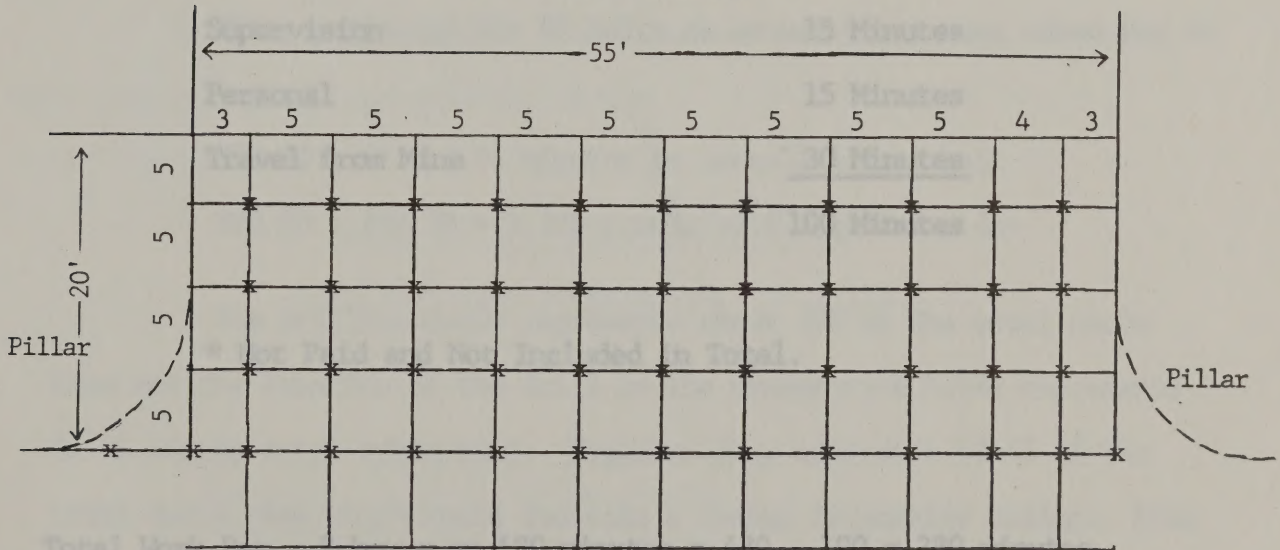
Floor - Irregular

Back - Smooth with no large fractures or irregular areas

TABLE II-

ROOF BOLTING PATTERN

First Round in Crosscut



FOR THIS ROUND 47 BOLTS/ROUND WERE REQUIRED

This chart is followed by a summary sheet which shows the total time, means, standard deviations and percent standard deviations for each cycle element.

ACTUAL WORK CYCLE

Roof Bolting - 1 operator - 1 drill

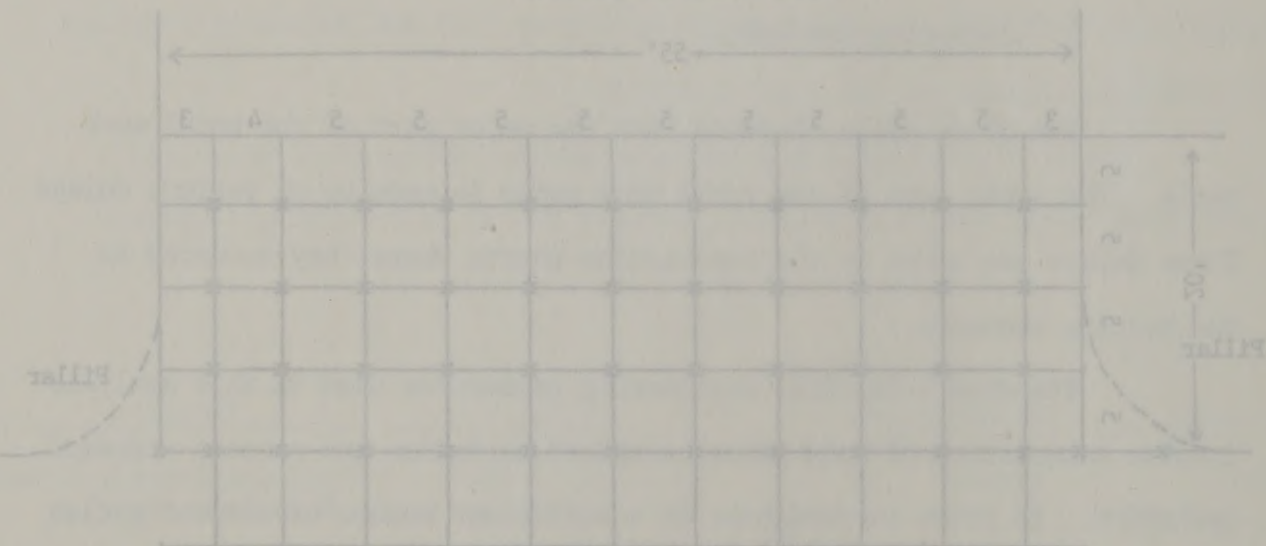
CONDITIONS:

Floor - Irregular
 Back - Smooth with no large fractures or irregular areas

TABLE II

ROOF BOLTING PATTERN

First Row in Circles



FOR THIS KIND OF BOLTING WORK REQUIRED

ACTUAL WORK CYCLE

Roof Bolting - 1 operator - 1 drill

Roof Bolting - 1 operator - 1 drill

CYCLE ELEMENT TOTALS FOR 47 (7') BOLTS

TOTAL TIME

POSSIBLE PRODUCTIVE WORK TIME:

(Assume 100% utilization of available time)

Allowances:

Travel to Work	30 Minutes
Travel to Lunch	5 Minutes
Lunch	30 Minutes *
Return to Work	5 Minutes
Supervision	15 Minutes
Personal	15 Minutes
Travel from Mine	<u>30 Minutes</u>
	100 Minutes

* Not Paid and Not Included in Total.

Total Work Day - 8 hours or 480 minutes = 480 - 100 = 380 minutes
(possible productive work time)

Actual Work Times - Starting Time	8:45 A.M.)	
Go to Lunch	11:56 A.M.)	191 Minutes
Return to Work	12:52 P.M.)	
Finish Bolting	2:21 P.M.)	<u>89 Minutes</u>
		280 Minutes

ACTUAL WORK CYCLE

Roof Bolting - 1 operator - 1 drill

POSSIBLE PRODUCTIVE WORK TIME:

(Assume 100% utilization of available time)

Allowances:

Travel to Work	30 Minutes
Travel to Lunch	5 Minutes
Lunch	30 Minutes *
Return to Work	5 Minutes
Supervision	15 Minutes
Personal	15 Minutes
Travel from Mine	30 Minutes
	<u>100 Minutes</u>

* Not Paid and Not Included in Total.

Total Work Day - 8 hours or 480 minutes = 480 - 100 = 380 minutes
(possible productive work time)

Actual Work Times - Starting Time	8:45 A.M.
Go to Lunch	11:58 A.M.
Return to Work	12:52 P.M.
Finish Bolting	3:51 P.M.
	<u>89 Minutes</u>
	280 Minutes

ACTUAL WORK CYCLE

Roof Bolting - 1 operator - 1 drill

<u>CYCLE ELEMENT TOTALS FOR 47 (7') BOLTS</u>	<u>TOTAL TIME</u>
1. Move in, set up, tear down, move out	35.56 Minutes
2. Locate and relocate on prospective hole	70.97 Minutes*
3. Collar the hole	1.41 Minutes
4. Drill the hole	97.76 Minutes
5. Retract the drill	11.28 Minutes
6. Insert the bolt	41.36 Minutes
7. Anchor the bolt	7.52 Minutes
8. Delay time	<u>14.00 Minutes</u>
TOTAL	279.86 Minutes

*Time projected for 47 bolts as actual times were taken for 46

$$279.80 \div 47 = 5.95 \text{ minutes to install 1 roof bolt}$$

$$380.00 \div 279.78 = 1.358 \text{ rounds roof bolted per day}$$

The drilling cycle represents about 35% of the total cycle time and the location of the drill on the prospective holes represents 25.4% of the total cycle time. Together they represent 60.4% of the total cycle time which would indicate a change in machine design. This change would be an increase in the number of drills on the roof bolting jumbo. Increasing the number of drills to four would cut down on the number of times the jumbo would have to be relocated on prospective holes and would increase the number of holes drilled in conjunction with each other thus making the roof bolt function more efficient.

ACTUAL WORK CYCLE

Roof Bolting - 1 operator - 1 drill

<u>CYCLE ELEMENT TOTALS FOR 47 (7') BOLTS</u>	<u>TOTAL TIME</u>
1. Move in, set up, tear down, move out	35.56 Minutes
2. Locate and relocate on prospective hole	70.97 Minutes
3. Collar the hole	1.41 Minutes
4. Drill the hole	97.76 Minutes
5. Retract the drill	11.38 Minutes
6. Insert the bolt	41.36 Minutes
7. Anchor the bolt	7.32 Minutes
8. Delay time	14.00 Minutes
TOTAL	279.86 Minutes

*Time projected for 47 bolts as actual times were taken for 46

$$279.86 \div 47 = 5.95 \text{ minutes to install 1 roof bolt}$$

$$360.00 - 279.76 = 80.24 \text{ minutes per day}$$

The drilling cycle represents about 35% of the total cycle time and the location of the drill on the prospective holes represents 25.4% of the total cycle time. Together they represent 60.4% of the total cycle time which would indicate a change in machine design. This change would be an increase in the number of drills on the roof bolting jumbo. Increasing the number of drills to four would cut down on the number of times the jumbo would have to be relocated on prospective holes and would increase the number of holes drilled in conjunction with each other thus making the roof bolt installation more efficient.

PROJECTED WORK CYCLE

Roof Bolting

PROJECTED ROOF BOLTING PROCEDURE FOR A COMMERCIAL OPERATION

In order to attain maximum efficiency in the roof bolting function the roof bolting jumbo will be a multiple drill; a completely mobile, self-contained unit. It will be a diesel powered, rubber-tired chassis equipped with a compressor, hydraulic pumps and storage for fuel, water, hydraulic fluid, roof bolts and roof bolt accessories. Power for the compressor and hydraulic pumps will be supplied by a diesel engine.

Table III shows a work cycle for a roof bolting jumbo equipped with four drills and operated by two men.

TABLE III - PROJECTED WORK CYCLE

Roof Bolting - 2 operators - 4 drills

Total time to roof bolt 1 round			
1 operator - 1 drill (minus delays			
and move in and move out time)	=	230.30	= 60.60
<u>Factor for 2 operators - 4 drills</u>		<u>3.8</u>	

	60.60
Move in - move out	35.56
Add delays	<u>14.00</u>
Total Time	110.16

PROJECTED WORK CYCLE

Roof Bolting

PROJECTED ROOF BOLTING PROCEDURE FOR A COMMERCIAL OPERATION

In order to obtain maximum efficiency in the roof bolting function the roof bolting jumbo will be a multiple drill; a completely mobile, self-contained unit. It will be a diesel powered, rubber-tired chassis equipped with a compressor, hydraulic pump and storage for fuel, water, hydraulic fluid, roof bolts and roof bolt accessories. Power for the compressor and hydraulic pump will be supplied by a diesel engine.

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TABLE III - PROJECTED WORK CYCLE

Roof Bolting - 2 operators - 4 drills

Total time to roof bolt 1 round	
1 operator - 1 drill (minus delays and move in and move out time)	230.30
Factor for 2 operators - 4 drills	3.8
<hr/>	
60.60	
32.56	Move in - move out
14.00	Add delays
<hr/>	
110.16	Total Time

ASSUME

8 hour or 480 minute work day (collar to collar)

ALLOWANCES

Travel to work place	10.00 Minutes
Lunch	30.00 Minutes *
Personal	15.00 Minutes
Supervision	10.00 Minutes
<hr/>	
Return to surface	<u>15.00 Minutes</u>
	80.00 Minutes

*Assume 5 minutes travel to lunch; 20 minutes lunch and 5 minutes return to work.

$480 - 80 = 400$ (possible productive work time)

$400 \div 110.16 = 3.631$ rounds roof bolted per 8 hour shift, or

approximately 72.621 rounds per week, based on 20 shifts per week.

ASSUMES

8 hour or 480 minute work day (collar to collar)

ALLOWANCES

Travel to work place	10.00 Minutes
Lunch	30.00 Minutes *
Personal	15.00 Minutes
Supervision	10.00 Minutes
Return to surface	<u>15.00 Minutes</u>
	80.00 Minutes

*Assumes 5 minutes travel to lunch; 20 minutes lunch and 5 minutes return to work.

480 - 80 = 400 (possible productive work time)

400 ÷ 110.16 = 3.631 rounds roof polished per 8 hour shift, or

approximately 72.631 rounds per week, based on 20 shifts per week.

ROOF BOLTING - LOCATION AND RELOCATION TIME IN MINUTES

Calculations to estimate true mean (M) from sample data.

$$\sum x = 69.46$$

$$N = 46$$

$$\bar{x} = 1.51$$

$$\sum x^2 = 109.02$$

$$S(x) = \sqrt{\frac{\sum x^2 - \bar{x}\sum x}{N-1}}$$

$$S(x) = \sqrt{\frac{109.02 - 1.51(69.46)}{46-1}}$$

$$S(x) = \sqrt{\frac{109.02 - 104.88}{45}} = \sqrt{\frac{4.14}{45}} = \sqrt{0.09} = 0.30$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}} = \frac{0.30}{\sqrt{46}} = \frac{0.30}{6.78} = 0.04$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{0.30}{\sqrt{46}} = \frac{0.30}{6.78} = 0.04$$

M @ 95% Confidence Level

$$M = \bar{x} \pm T_{0.05} S(\bar{x})$$

$$M = 1.51 \pm 2.014 (.04)$$

$$M = 1.51 \pm 0.09 \text{ minutes}$$

POOL WAITING - LOCATION AND RELOCATION TIME IN MINUTES

Calculations to estimate true mean (μ) from sample data.

$$\begin{aligned} \bar{x} &= 69.46 \\ n &= 46 \\ s^2 &= 1.21 \\ s &= 1.0902 \end{aligned}$$

$$s(x) = \sqrt{\frac{s^2 - 1}{n-1}}$$

$$s(x) = \sqrt{\frac{1.0902 - 1.21(69.46)}{46-1}}$$

$$s(x) = \sqrt{\frac{1.0902 - 1.0488}{46}} = \sqrt{\frac{0.0414}{46}} = 0.0947 = 0.30$$

$$s(x) = \frac{s(x)}{\sqrt{n}}$$

$$s(x) = \frac{0.30}{\sqrt{46}} = \frac{0.30}{6.78} = 0.04$$

95% Confidence Level

$$M = \bar{x} \pm 0.05 s(x)$$

$$M = 1.21 \pm 2.014 (0.04)$$

$$M = 1.21 \pm 0.08 \text{ minutes}$$

ROOF BOLTING - COLLARING THE HOLE

Calculations to estimate true mean (M) from sample data.

$$s_x = 1.41$$

$$N = 47$$

$$\bar{x} = 0.03$$

$$s_x^2 = 0.0492$$

$$S(x) = \sqrt{\frac{s_x^2 - \bar{x} s_x}{N-1}}$$

$$S(x) = \sqrt{\frac{0.0492 - 0.03(1.41)}{47-1}}$$

$$S(x) = \sqrt{\frac{0.0492 - 0.0423}{46}} = \sqrt{\frac{0.0069}{46}} = \sqrt{0.0002} \quad 0.122$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{0.0122}{\sqrt{47}} = \frac{0.0122}{6.8557} = .0018$$

M @ 95% Confidence Level

$$M = \bar{x} \pm T_{0.05} S(\bar{x})$$

$$M = 0.03 \pm 2.0133 (.0018)$$

$$M = 0.03 \pm 0.0036 \text{ minutes}$$

HOPE BOILING - COLLARING THE HOLE

Calculation to estimate true mean $\bar{\mu}$ from sample data.

$$\begin{aligned} \bar{x} &= 1.41 \\ n &= 47 \\ \bar{s} &= 0.03 \\ s^2 &= 0.0009 \end{aligned}$$

$$s(x) = \sqrt{\frac{s^2 - \bar{s}^2}{n-1}}$$

$$s(x) = \sqrt{\frac{0.0009 - 0.03(1.41)}{47-1}}$$

$$s(x) = \sqrt{\frac{0.0009 - 0.0423}{46}} = \sqrt{\frac{0.0009}{46}} = \sqrt{0.0002} = 0.133$$

$$s(x) = \frac{s(x)}{\sqrt{n}}$$

$$s(x) = \frac{0.133}{\sqrt{47}} = \frac{0.133}{6.827} = 0.018$$

M @ 95% Confidence Level

$$M = \bar{x} \pm 1.96 s(x)$$

$$M = 0.03 \pm 2.018 (0.018)$$

$$M = 0.03 \pm 0.036 \text{ inches}$$

ROOF BOLTING - DRILLING THE HOLE

Calculations to estimate true mean (M) from sample data.

$$\sum x = 97.76$$

$$N = 47$$

$$\bar{x} = 2.08$$

$$\sum x^2 = 206.84$$

$$S(x) = \sqrt{\frac{\sum x^2 - \bar{x} \sum x}{N-1}}$$

$$S(x) = \sqrt{\frac{206.84 - (2.08)(97.76)}{47-1}}$$

$$S(x) = \sqrt{\frac{206.84 - 203.34}{46}} = \sqrt{\frac{3.50}{46}} = \sqrt{0.08} = 0.28$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{0.28}{\sqrt{47}} = \frac{0.28}{6.68} = 0.04$$

M @ 95% Confidence Level

$$M = \bar{x} \pm T_{0.05} S(\bar{x})$$

$$M = 2.08 \pm 2.013 (0.04)$$

$$M = 2.08 \pm 0.08 \text{ minutes}$$

BOX PLOT - FINDING THE MEAN

Calculations to estimate true mean (μ) from sample data.

$$\begin{aligned} \bar{x} &= 97.76 \\ n &= 47 \\ s &= 2.08 \\ \bar{x}_2 &= 208.84 \end{aligned}$$

$$s(x) = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}}$$

$$s(x) = \sqrt{\frac{208.84 - (2.08)(97.76)}{47-1}}$$

$$s(x) = \sqrt{\frac{208.84 - 203.34}{46}} = \sqrt{\frac{5.50}{46}} = \sqrt{0.12} = 0.35$$

$$s(x) = \frac{s(x)}{\sqrt{n}}$$

$$s(x) = \frac{0.35}{\sqrt{47}} = \frac{0.35}{6.86} = 0.05$$

95% Confidence Level

$$n = 2 \pm 1.96 s(x)$$

$$n = 2.08 \pm 1.96(0.05)$$

$$n = 2.08 \pm 0.09$$

ROOF BOLTING - RETRACT DRILL

Calculations to estimate true mean (M) from sample data.

$$\sum x = 11.28$$

$$N = 47$$

$$\bar{x} = 0.24$$

$$\sum x^2 = 2.68$$

$$S(x) = \sqrt{\frac{\sum x^2 - \bar{x} \sum x}{N-1}}$$

$$S(x) = \sqrt{\frac{2.68 - 0.24(11.28)}{47-1}}$$

$$S(x) = \sqrt{\frac{2.68 - 2.70}{46}} = \sqrt{\frac{-0.02}{46}} = \sqrt{.00043} = .0208$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{.0208}{\sqrt{47}} = \frac{.0208}{6.85} = 0.003$$

M @ 95% Confidence Level

$$M = \bar{x} \pm T_{0.05} S(\bar{x})$$

$$M = 0.24 \pm 2.013 (0.003)$$

$$M = 0.24 \pm 0.006 \text{ minutes}$$

ROOF BOLTING - RETRACT DRILL

Calculations to estimate true mean (μ) from sample data.

$$\begin{aligned} \bar{x} &= 11.28 \\ n &= 47 \\ \bar{y} &= 0.24 \\ s_x^2 &= 2.68 \end{aligned}$$

$$\begin{aligned} s(x) &= \sqrt{\frac{s_x^2 - \bar{y}^2}{n-1}} \\ s(x) &= \sqrt{\frac{2.68 - 0.24(11.28)}{47-1}} \\ s(x) &= \sqrt{\frac{2.68 - 2.70}{46}} = \sqrt{\frac{-0.02}{46}} = \sqrt{0.00043} = 0.0208 \end{aligned}$$

$$\begin{aligned} s(x) &= \frac{s(x)}{\sqrt{n}} \\ s(x) &= \frac{0.0208}{\sqrt{47}} = \frac{0.0208}{6.82} = 0.003 \end{aligned}$$

95% Confidence Level

$$\begin{aligned} \bar{x} &= 11.28 \pm 2s(x) \\ \bar{x} &= 11.28 \pm 2(0.003) \\ \bar{x} &= 11.28 \pm 0.006 \end{aligned}$$

ROOF BOLTING - INSERT ROOF BOLT

Calculations to estimate true mean (M) from sample data.

$$\sum x = 41.36$$

$$N = 47$$

$$\bar{x} = 0.88$$

$$\sum x^2 = 36.19$$

$$S(x) = \sqrt{\frac{\sum x^2 - \bar{x} \sum x}{N-1}}$$

$$S(x) = \sqrt{\frac{36.19 - .88(41.36)}{47-1}}$$

$$S(x) = \sqrt{\frac{36.19 - 36.40}{46}} = \sqrt{\frac{-.21}{46}} = \sqrt{.0046} = 0.0676$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{.0676}{\sqrt{47}} = \frac{.0676}{6.85} = .0099$$

M @ 95% Confidence Level

$$M = \bar{x} \pm T_{0.05} S(\bar{x})$$

$$M = 0.88 \pm 2.93 (.0099)$$

$$M = 0.88 \pm 0.0199 \text{ minutes}$$

ROOF WATERS - INSERT ROOF BOLT

Calculations to estimate true mean (Q) from sample data.

$$\sum x = 41.36$$

$$N = 47$$

$$\bar{x} = 0.88$$

$$\sum x^2 = 36.19$$

$$s(x) = \sqrt{\frac{\sum x^2 - \bar{x}^2 N}{N-1}}$$

$$s(x) = \sqrt{\frac{36.19 - .88(41.36)}{47-1}}$$

$$s(x) = \sqrt{\frac{36.19 - 36.40}{46}} = \sqrt{\frac{-.21}{46}} = \sqrt{.0046} = 0.0676$$

$$s(x) = \frac{s(x)}{\sqrt{N}}$$

$$s(x) = \frac{.0676}{\sqrt{47}} = \frac{.0676}{6.85} = .0099$$

95% Confidence Level

$$M = \bar{x} \pm t(0.025, 46)$$

$$M = 0.88 \pm 2.01(.0099)$$

$$M = 0.88 \pm 0.0203$$

ROOF BOLTING - ANCHOR BOLT

October 1975

Calculations to estimate true mean (M) from sample data.

$$\sum x = 7.52$$

$$N = 47$$

$$\bar{x} = .16$$

$$\sum x^2 = 1.37$$

$$S(x) = \sqrt{\frac{\sum x^2 - \bar{x} \sum x}{N-1}}$$

$$S(x) = \sqrt{\frac{1.37 - (.16)(7.52)}{47-1}}$$

$$S(x) = \sqrt{\frac{1.37 - 1.20}{46}} = \sqrt{\frac{.17}{46}} \sqrt{.0036} = .06079$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{.06}{\sqrt{47}} = \frac{.06079}{6.85} = .0088$$

M @ 95% Confidence Level

$$M = \bar{x} \pm T_{0.05} S(\bar{x})$$

$$M = .16 \pm 2.013 (.0088)$$

$$M = .16 \pm .017 \text{ minutes}$$

MOOF BOLTING - ANCHOR BOLT

Calculations to estimate true mean (μ) from sample data.

$$\begin{aligned} \bar{x} &= 1.16 \\ n &= 47 \\ s^2 &= 1.37 \\ s &= 1.17 \end{aligned}$$

$$s(x) = \sqrt{\frac{s^2}{n-1}} = \sqrt{\frac{1.37}{46}} = 0.17$$

$$s(x) = \sqrt{\frac{s^2}{n-1}} = \sqrt{\frac{1.37}{46}} = 0.17$$

$$s(x) = \sqrt{\frac{s^2}{n-1}} = \sqrt{\frac{1.37}{46}} = 0.17$$

$$s(x) = \sqrt{\frac{s^2}{n-1}} = 0.17$$

$$s(x) = \sqrt{\frac{s^2}{n-1}} = 0.17$$

95% Confidence Interval

$$n = 47$$

$$n = 47$$

$$n = 47$$

MAN/MACHINE TIME CHARTActual Roof Bolting - Anvil Points MineOctober 1975

<u>HOLE NO.</u>	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
1	Move into face	2.40	2.40
	Set up to bolt	24.00	26.40
	Collar hole	.05	26.45
	Drill hole	2.36	28.81
	Retract drill	.23	29.04
	Insert bolt	1.24	30.28
	Anchor bolt	.13	30.41
2	Relocate	1.42	31.83
	Collar hole	.08	31.91
	Drill hole	2.42	34.33
	Retract drill	.22	34.55
	Insert bolt	.91	35.46
	Anchor bolt	.13	35.59
3	Relocate	2.00	37.59
	Collar hole	.04	37.63
	Drill hole	2.09	39.72
	Retract drill	.21	39.93
	Insert bolt	.85	40.78
	Anchor bolt	.12	40.90
4	Relocate	1.11	42.01
	Collar hole	.03	42.04
	Drill hole	2.11	44.15
	Retract drill	.22	44.37
	Insert bolt	.88	45.25
	Anchor bolt	.13	45.38
5	Relocate	2.00	47.38
	Collar hole	.04	47.42
	Drill hole	2.02	49.44
	Retract drill	.24	49.68
	Insert bolt	.88	50.56
	Anchor bolt	.19	50.75
6	Relocate	1.48	52.23
	Collar hole	.03	52.26
	Drill hole	2.58	54.84
	Retract drill	.23	55.07
	Insert bolt	.87	55.94
	Anchor bolt	.13	56.07

MANUWRITE TIME CHART

Actual Rock Bolting - Anvil Pointe Mine

October 1975

WELL NO.	ELEMENT	TIME	CUMULATIVE TIME
1	Move into face	2.40	2.40
	Set up to bolt	24.00	26.40
	Collar hole	.02	26.42
	Drill hole	2.36	28.81
	Retract drill	.23	29.04
	Insert bolt	1.24	30.28
	Anchor bolt	.13	30.41
2	Relocate	1.42	31.83
	Collar hole	.08	31.91
	Drill hole	2.42	34.33
	Retract drill	.22	34.55
	Insert bolt	.91	35.46
	Anchor bolt	.13	35.59
3	Relocate	2.00	37.59
	Collar hole	.04	37.63
	Drill hole	2.09	39.72
	Retract drill	.21	39.93
	Insert bolt	.82	40.75
	Anchor bolt	.12	40.87
4	Relocate	1.11	42.01
	Collar hole	.03	42.04
	Drill hole	2.11	44.15
	Retract drill	.22	44.37
	Insert bolt	.88	45.25
	Anchor bolt	.13	45.38
5	Relocate	2.00	47.38
	Collar hole	.04	47.42
	Drill hole	2.02	49.44
	Retract drill	.24	49.68
	Insert bolt	.88	50.56
	Anchor bolt	.19	50.75
6	Relocate	1.48	52.23
	Collar hole	.03	52.26
	Drill hole	2.28	54.54
	Retract drill	.23	54.77
	Insert bolt	.87	55.64
	Anchor bolt	.13	55.77

MAN/MACHINE TIME CHARTActual Roof Bolting - Anvil Points MineOctober 1975

<u>HOLE NO.</u>	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
7	Relocate	1.54	57.61
	Collar hole	.04	57.65
	Drill hole	2.22	59.87
	Retract drill	.20	60.07
	Insert bolt	.91	60.98
	Anchor bolt	.15	61.13
8	Relocate	1.58	62.71
	Collar hole	.02	62.73
	Drill hole	2.13	64.86
	Retract drill	.23	65.09
	Insert bolt	.85	65.94
	Anchor bolt	.18	66.12
9	Relocate	2.14	68.26
	Collar hole	.03	68.29
	Drill hole	2.93	71.22
	Retract drill	.24	71.46
	Insert bolt	.89	72.35
	Anchor bolt	.12	72.47
10	Relocate	1.20	73.67
	Collar hole	.03	73.70
	Drill hole	2.21	75.91
	Retract drill	.24	76.15
	Insert bolt	.86	77.01
	Anchor bolt	.09	77.10
11	Relocate	1.62	78.72
	Collar hole	.03	78.75
	Drill hole	2.17	80.92
	Retract drill	.23	81.15
	Insert bolt	.83	81.98
	Anchor bolt	.09	82.07
12	Relocate	1.88	83.95
	Collar hole	.03	83.98
	Drill hole	2.28	86.26
	Retract drill	.24	86.50
	Insert bolt	1.26	87.76
	Anchor bolt	.14	87.90

1934 OCT 20 1934

1934 OCT 20 1934

1934 OCT 20 1934

SECTION ONE

SECTION TWO

SECTION THREE

MAN/MACHINE TIME CHART

Actual Roof Bolting - Anvil Points Mine

October 1975

<u>HOLE NO.</u>	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
13	Relocate	1.11	89.01
	Collar hole	.03	89.04
	Drill hole	1.98	91.02
	Retract drill	.22	91.24
	Insert bolt	.78	92.02
	Anchor bolt	.13	92.15
14	Relocate	1.35	93.50
	Collar hole	.04	93.54
	Drill hole	2.06	95.60
	Retract drill	.23	95.83
	Insert bolt	.86	96.69
	Anchor bolt	.18	96.87
15	Relocate	1.42	98.29
	Collar hole	.03	98.32
	Drill hole	2.12	100.44
	Retract drill	.23	100.67
	Insert bolt	.81	101.48
	Anchor bolt	.13	101.61
16	Relocate	1.89	103.50
	Collar hole	.04	103.54
	Drill hole	2.22	105.76
	Retract drill	.29	106.05
	Insert bolt	.77	106.82
	Anchor bolt	.15	106.97
17	Relocate	1.39	108.36
	Collar hole	.03	108.39
	Drill hole	1.98	110.37
	Retract drill	.22	110.59
	Insert bolt	.84	111.43
	Anchor bolt	.16	111.59
18	Relocate	1.46	113.05
	Collar hole	.02	113.07
	Drill hole	2.02	115.09
	Retract drill	.25	115.34
	Insert bolt	.83	116.17
	Anchor bolt	.16	116.33

ANALOGUE TIME TABLE

Actual Road Building - Actual Points Mile

October 1975

CUMULATIVE TIME	TIME	EVENT	ROUTE NO.
89.01	1.11	Relocate	13
89.04	.03	Collar hole	
89.07	1.98	Drill hole	
89.10	.72	Retract drill	
89.13	.78	Insert hole	
89.15	.13	Anchor hole	
89.30	1.35	Relocate	14
89.34	.04	Collar hole	
89.38	2.08	Drill hole	
89.41	.23	Retract drill	
89.44	.66	Insert hole	
89.47	.18	Anchor hole	
89.59	1.43	Relocate	15
89.62	.03	Collar hole	
89.65	2.12	Drill hole	
89.67	.23	Retract drill	
89.69	.81	Insert hole	
89.71	.13	Anchor hole	
89.86	1.89	Relocate	16
89.90	.04	Collar hole	
89.93	2.23	Drill hole	
89.95	.29	Retract drill	
89.97	.73	Insert hole	
89.99	.15	Anchor hole	
90.14	1.39	Relocate	17
90.18	.03	Collar hole	
90.21	1.98	Drill hole	
90.24	.23	Retract drill	
90.27	.84	Insert hole	
90.29	.16	Anchor hole	
90.45	1.46	Relocate	18
90.49	.03	Collar hole	
90.52	2.02	Drill hole	
90.54	.23	Retract drill	
90.57	.83	Insert hole	
90.59	.16	Anchor hole	

MAN/MACHINE TIME CHARTActual Roof Bolting - Anvil Points MineOctober 1975

<u>HOLE NO.</u>	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
19	Relocate	1.21	117.54
	Collar hole	.02	117.56
	Drill hole	1.96	119.52
	Retract drill	.21	119.73
	Insert bolt	.82	120.55
	Anchor bolt	.12	120.67
20	Relocate	2.09	122.76
	Collar hole	.03	122.79
	Drill hole	2.01	124.80
	Retract drill	.24	125.04
	Insert bolt	.88	125.92
	Anchor bolt	.18	126.10
21	Relocate	1.36	127.46
	Collar hole	.03	127.49
	Drill hole	2.04	129.53
	Retract drill	.24	129.77
	Insert bolt	.82	130.59
	Anchor bolt	.21	130.80
22	Relocate	1.36	132.16
	Collar hole	.03	132.19
	Drill hole	2.02	134.21
	Retract drill	.23	134.44
	Insert bolt	.88	135.32
	Anchor bolt	.18	135.50
23	Relocate	1.35	136.85
	Collar hole	.02	136.87
	Drill hole	2.26	139.13
	Retract drill	.23	139.36
	Insert bolt	.84	140.20
	Anchor bolt	.12	140.32
	DELAY - get more bolts and plates	9.00	149.32
24	Relocate	1.51	150.83
	Collar hole	.03	150.86
	Drill hole	2.18	153.04
	Retract drill	.24	153.28
	Insert bolt	.83	154.11
	Anchor bolt	.23	154.34

MEASUREMENT TIME CHART

Actual Root Position - Actual Position Time

October 1975

DATE	TIME	EVENT	TIME
10	1.31	Relocate	117.38
	.85	Collar hole	117.38
	1.04	Drill hole	119.32
	.21	Retract drill	119.53
	.85	Insert hole	120.38
	.12	Anchor hole	120.50
10	2.03	Relocate	122.38
	.03	Collar hole	122.38
	2.01	Drill hole	124.39
	.24	Retract drill	125.04
	.88	Insert hole	125.92
	.18	Anchor hole	126.10
11	1.36	Relocate	127.46
	.49	Collar hole	127.46
	2.04	Drill hole	129.30
	.26	Retract drill	129.56
	.82	Insert hole	130.38
	.21	Anchor hole	130.59
12	1.36	Relocate	132.34
	.03	Collar hole	132.34
	2.05	Drill hole	134.31
	.23	Retract drill	134.54
	.88	Insert hole	135.32
	.18	Anchor hole	135.50
13	1.35	Relocate	136.87
	.03	Collar hole	136.87
	2.26	Drill hole	139.13
	.28	Retract drill	139.38
	.86	Insert hole	140.20
	.12	Anchor hole	140.32
	9.00	WELT - get more bolts and plates	149.32
14	1.32	Relocate	150.87
	.03	Collar hole	150.88
	2.18	Drill hole	152.04
	.24	Retract drill	152.28
	.82	Insert hole	153.10
	.23	Anchor hole	153.34

MAN/MACHINE TIME CHART

Actual Roof Bolting - Anvil Points Mine

October 1975

<u>HOLE NO.</u>	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
25	Relocate	1.38	155.72
	Collar hole	.04	155.76
	Drill hole	1.97	157.73
	Retract drill	.24	157.97
	Insert bolt	.90	158.87
	Anchor bolt	.13	159.00
26	Relocate	1.19	160.19
	Collar hole	.03	160.22
	Drill hole	2.57	162.79
	Retract drill	.25	163.04
	Insert bolt	.87	163.91
	Anchor bolt	.12	164.03
27	Relocate	1.69	165.72
	Collar hole	.03	165.75
	Drill hole	2.02	167.77
	Retract drill	.29	168.06
	Insert bolt	.91	168.97
	Anchor bolt	.20	169.17
28	Relocate	1.41	170.58
	Collar hole	.04	170.62
	Drill hole	2.09	172.71
	Retract drill	.21	172.92
	Insert bolt	.89	173.81
	Anchor bolt	.12	173.93
29	Relocate	1.19	175.12
	Collar hole	.02	175.14
	Drill hole	2.03	177.17
	Retract drill	.23	177.40
	Insert bolt	.86	178.26
	Anchor bolt	.16	178.42
30	Relocate	1.51	179.93
	Collar hole	.03	179.96
	Drill hole	2.45	182.41
	Retract drill	.25	182.66
	Insert bolt	.94	183.60
	Anchor bolt	.21	183.81

MINING THE CHART

Actual Root Rating - Actual Potable Mine

October 1975

DATE	TIME	MEASUREMENT	WELL NO.
125.75	1.38	Relocated	25
125.76	.04	Collar hole	
127.73	1.97	Drill hole	
127.97	.24	Retreat drill	
128.87	.90	Insert hole	
129.00	.13	Anchor hole	
160.19	1.19	Relocated	26
160.33	.08	Collar hole	
162.79	2.57	Drill hole	
163.04	.25	Retreat drill	
163.91	.87	Insert hole	
164.03	.13	Anchor hole	
165.73	1.69	Relocated	27
165.75	.03	Collar hole	
167.77	2.02	Drill hole	
168.06	.20	Retreat drill	
168.97	.91	Insert hole	
169.19	.20	Anchor hole	
170.58	1.41	Relocated	28
170.63	.04	Collar hole	
172.71	2.09	Drill hole	
172.92	.21	Retreat drill	
173.81	.89	Insert hole	
173.93	.13	Anchor hole	
175.13	1.19	Relocated	29
175.16	.02	Collar hole	
177.17	2.03	Drill hole	
177.40	.23	Retreat drill	
178.36	.66	Insert hole	
178.45	.16	Anchor hole	
179.93	1.31	Relocated	30
179.96	.03	Collar hole	
182.41	2.43	Drill hole	
183.66	.25	Retreat drill	
183.80	.94	Insert hole	
183.81	.21	Anchor hole	

MAN/MACHINE TIME CHART

Actual Roof Bolting - Anvil Points Mine

October 1975

<u>HOLE NO.</u>	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
31	Relocate	1.74	185.55
	Collar hole	.02	185.57
	Drill hole	2.49	188.06
	Retract drill	.22	188.28
	Insert bolt	.94	189.22
	Anchor bolt	.13	189.35
32	Relocate	1.23	190.58
	Collar hole	.03	190.61
	Drill hole	1.91	192.52
	Retract drill	.26	192.78
	Insert bolt	.87	193.65
	Anchor bolt	.26	193.91
33	Relocate	1.26	195.17
	Collar hole	.03	195.20
	Drill hole	2.08	197.28
	Retract drill	.26	197.54
	Insert bolt	.99	198.53
	Anchor bolt	.14	198.67
34	Relocate	1.86	200.53
	Collar hole	.02	200.55
	Drill hole	1.86	202.41
	Retract drill	.22	202.63
	Insert bolt	1.19	203.82
	Anchor bolt	.16	203.98
35	Relocate	1.31	205.29
	Collar hole	.04	205.33
	Drill hole	1.12	206.45
	Retract drill	.28	206.73
	Insert bolt	.86	207.59
	Anchor bolt	.18	207.77
36	Relocate	1.42	209.19
	Collar hole	.03	209.22
	Drill hole	2.08	211.30
	Retract drill	.26	211.56
	Insert bolt	.85	212.41
	Anchor bolt	.15	212.56

MANAGEMENT THE GARD

Actual Road Building - Actual Points Mile

October 1975

REL NO.	FLIGHT	TIME	CUMULATIVE TIME
31	Relocate	1.74	183.32
	Collar hole	.02	183.37
	Drill hole	2.49	188.08
	Recharge drill	.22	188.38
	Insert hole	.94	189.32
	Anchor hole	.13	189.35
32	Relocate	1.23	190.38
	Collar hole	.03	190.61
	Drill hole	1.91	192.52
	Recharge drill	.26	192.78
	Insert hole	.67	193.65
	Anchor hole	.26	193.91
33	Relocate	1.26	195.17
	Collar hole	.03	195.20
	Drill hole	2.08	197.28
	Recharge drill	.26	197.54
	Insert hole	.99	198.53
	Anchor hole	.14	198.67
34	Relocate	1.86	200.53
	Collar hole	.02	200.55
	Drill hole	1.58	202.41
	Recharge drill	.22	202.63
	Insert hole	1.19	203.82
	Anchor hole	.16	203.98
35	Relocate	1.31	205.29
	Collar hole	.04	205.33
	Drill hole	1.12	206.48
	Recharge drill	.28	206.73
	Insert hole	.86	207.59
	Anchor hole	.16	207.77
36	Relocate	1.42	209.19
	Collar hole	.03	209.22
	Drill hole	2.08	211.30
	Recharge drill	.26	211.56
	Insert hole	.85	212.41
	Anchor hole	.15	212.56

MAN/MACHINE TIME CHARTActual Roof Bolting - Anvil Points MineOctober 1975

<u>HOLE NO.</u>	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
37	Relocate	1.15	213.71
	Collar hole	.02	213.73
	Drill hole	1.88	215.61
	Retract drill	.24	215.85
	Insert bolt	.81	216.66
	Anchor bolt	.15	216.81
38	Relocate	1.06	217.87
	Collar hole	.03	217.90
	Drill hole	2.07	219.97
	Retract drill	.25	220.22
	Insert bolt	.83	221.05
	Anchor bolt	.19	221.24
39	Relocate	1.77	223.01
	Collar hole	.02	223.03
	Drill hole	1.95	224.98
	Retract drill	.22	225.20
	Insert bolt	.89	226.09
	Anchor bolt	.33	226.42
40	Relocate	1.21	227.63
	Collar hole	.03	227.66
	Drill hole	1.76	229.42
	Retract drill	.23	229.65
	Insert bolt	.79	230.44
	Anchor bolt	.16	230.60
41	Relocate	1.13	231.73
	Collar hole	.02	231.75
	Drill hole	1.89	233.64
	Retract drill	.26	233.90
	Insert bolt	.82	234.72
	Anchor bolt	.17	234.89
42	Relocate	1.82	236.71
	Collar hole	.03	236.74
	Drill hole	1.86	238.60
	Retract drill	.24	238.84
	Insert bolt	.80	239.64
	Anchor bolt	.22	239.86

MINING MACHINE TIME CARD

Actual Road Building - Anvil Point Mine

October 1975

DATE	TIME	EVENT	WORK NO.
213.71	1.15	Relocate	37
213.73	.02	Collar hole	
213.81	1.88	Drill hole	
213.83	.24	Retract drill	
213.88	.81	Insert bolt	
213.91	.15	Anchor bolt	
217.87	1.06	Relocate	38
217.90	.03	Collar hole	
219.97	2.07	Drill hole	
220.22	.25	Retract drill	
221.05	.83	Insert bolt	
221.24	.19	Anchor bolt	
227.01	1.77	Relocate	39
227.03	.02	Collar hole	
224.98	1.95	Drill hole	
225.20	.22	Retract drill	
226.09	.89	Insert bolt	
226.42	.33	Anchor bolt	
227.63	1.21	Relocate	40
227.66	.03	Collar hole	
229.42	1.76	Drill hole	
229.62	.23	Retract drill	
230.44	.79	Insert bolt	
230.60	.16	Anchor bolt	
231.73	1.13	Relocate	41
231.75	.02	Collar hole	
233.84	1.89	Drill hole	
233.90	.26	Retract drill	
234.72	.82	Insert bolt	
234.89	.17	Anchor bolt	
238.71	1.87	Relocate	42
238.74	.03	Collar hole	
238.80	1.86	Drill hole	
238.84	.24	Retract drill	
239.64	.80	Insert bolt	
239.86	.22	Anchor bolt	

MAN/MACHINE TIME CHART

Actual Roof Bolting - Arvill Points Mine

October 1975

<u>HOLE NO.</u>	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
43	Relocate	1.70	241.56
	Collar hole	.03	241.59
	Drill hole	1.79	243.38
	Retract drill	.26	243.64
	Insert bolt	.81	244.45
	Anchor bolt	.16	244.61
44	Relocate	1.64	246.25
	Collar hole	.04	246.29
	Drill hole	1.86	248.15
	Retract drill	.25	248.40
	Insert bolt	.78	249.18
	Anchor bolt	.18	249.36
45	Relocate	1.72	251.08
	Collar hole	.02	251.10
	Drill hole	1.86	252.96
	Retract drill	.25	253.21
	Insert bolt	.88	254.09
	Anchor bolt	.15	254.24
46	Relocate	2.32	256.56
	Collar hole	.02	256.58
	Drill hole	1.88	258.46
	Retract drill	.23	258.69
	Insert bolt	.94	259.63
	Anchor bolt	.17	259.80
	DELAY - get one bolt	5.00	264.80
47	Relocate	1.26	266.06
	Collar hole	.02	266.08
	Drill hole	1.96	268.04
	Retract drill	.27	268.31
	Insert bolt	.86	269.17
	Anchor bolt	.18	269.35
	Tear down, move out	9.00	278.35

WATERMINE TIME CHART

Annual Book Binding - Arrow Point Mine

October 1975

FILE NO.	EVENT	TIME	CUMULATIVE TIME
43	Relocate	1.70	241.28
	Collar hole	.03	241.31
	Drill hole	1.79	243.10
	Retreat drill	.26	243.36
	Insert bolt	.81	244.17
	Anchor bolt	.16	244.33
44	Relocate	1.64	245.97
	Collar hole	.04	246.01
	Drill hole	1.86	247.87
	Retreat drill	.22	248.09
	Insert bolt	.78	248.87
	Anchor bolt	.18	249.05
45	Relocate	1.32	250.37
	Collar hole	.03	250.40
	Drill hole	1.86	252.26
	Retreat drill	.22	252.48
	Insert bolt	.89	253.37
	Anchor bolt	.12	253.49
46	Relocate	2.32	255.81
	Collar hole	.02	255.83
	Drill hole	1.88	257.71
	Retreat drill	.22	257.93
	Insert bolt	.94	258.87
	Anchor bolt	.17	259.04
	DELAY - get one bolt	2.00	261.04
	Relocate	1.26	262.30
47	Collar hole	.02	262.32
	Drill hole	1.94	264.26
	Retreat drill	.27	264.53
	Insert bolt	.86	265.39
	Anchor bolt	.18	265.57
	Test line, move out	2.00	267.57
			269.57

MAN/MACHINE TIME CHART

Actual Roof Bolting - Anvil Points Mine

October 1975

SUMMARY SHEET

	<u>Total Time</u>	<u>Occurrences of Cycle Elements</u>	<u>Mean</u>	<u>Standard Deviation</u>	<u>%</u>
1. Move in, set up, tear down, move out	35.56	2	17.78	12.30	70%
2. Locate and relocate on prospective hole	69.46	46	1.51	0.30	20%
3. Collar the hole	1.41	47	0.03	0.01	35%
4. Drill the hole	97.76	47	2.08	0.27	13%
5. Retract the drill	11.28	47	0.24	0.02	8%
6. Insert the bolt	41.36	47	0.88	0.10	12%
7. Anchor the bolt	7.52	47	0.16	0.04	29%
8. Delays	<u>14.00</u>	2	-	-	-
	278.35				

MANUACHINE THE GWT

Actual Rock Bolting - Avati Pointa Mine

October 1975

SUMMARY SHEET

	Standard Deviation %	Mean	Occurrences of Cycle Elements	Total Time	
1. Move in, set up, test down, move out	12.30	17.78	2	35.56	
2. Locate and relocate on prospective hole	0.30	1.51	46	69.46	
3. Collar the hole	0.01	0.03	47	1.41	
4. Drill the hole	0.27	2.08	47	97.76	
5. Retract the drill	0.03	0.24	47	11.28	
6. Insert the bolt	0.10	0.88	47	41.36	
7. Anchor the bolt	0.04	0.16	47	7.52	
8. Delay	-	-	2	14.00	
				278.35	

FIGURE I

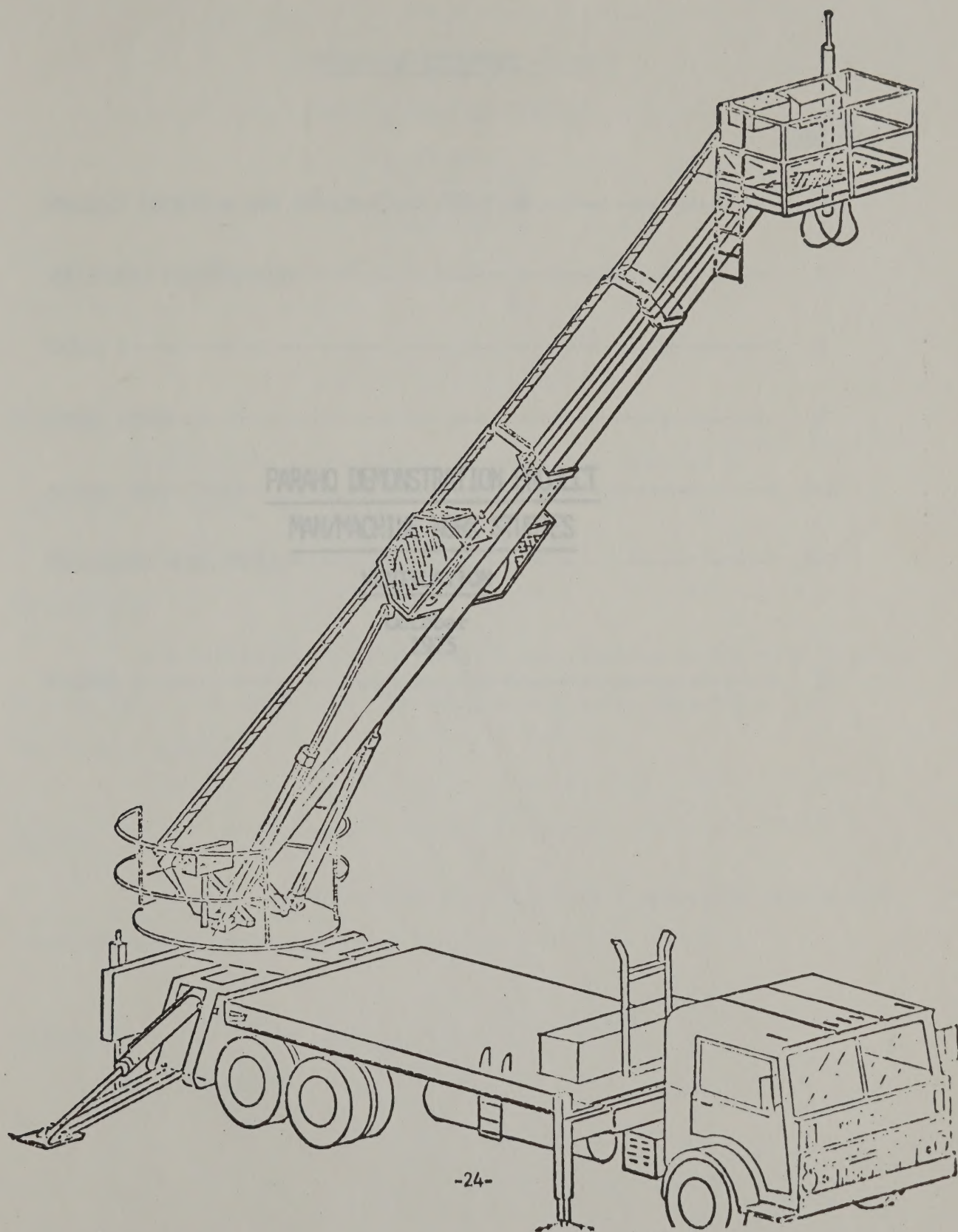


FIGURE 1

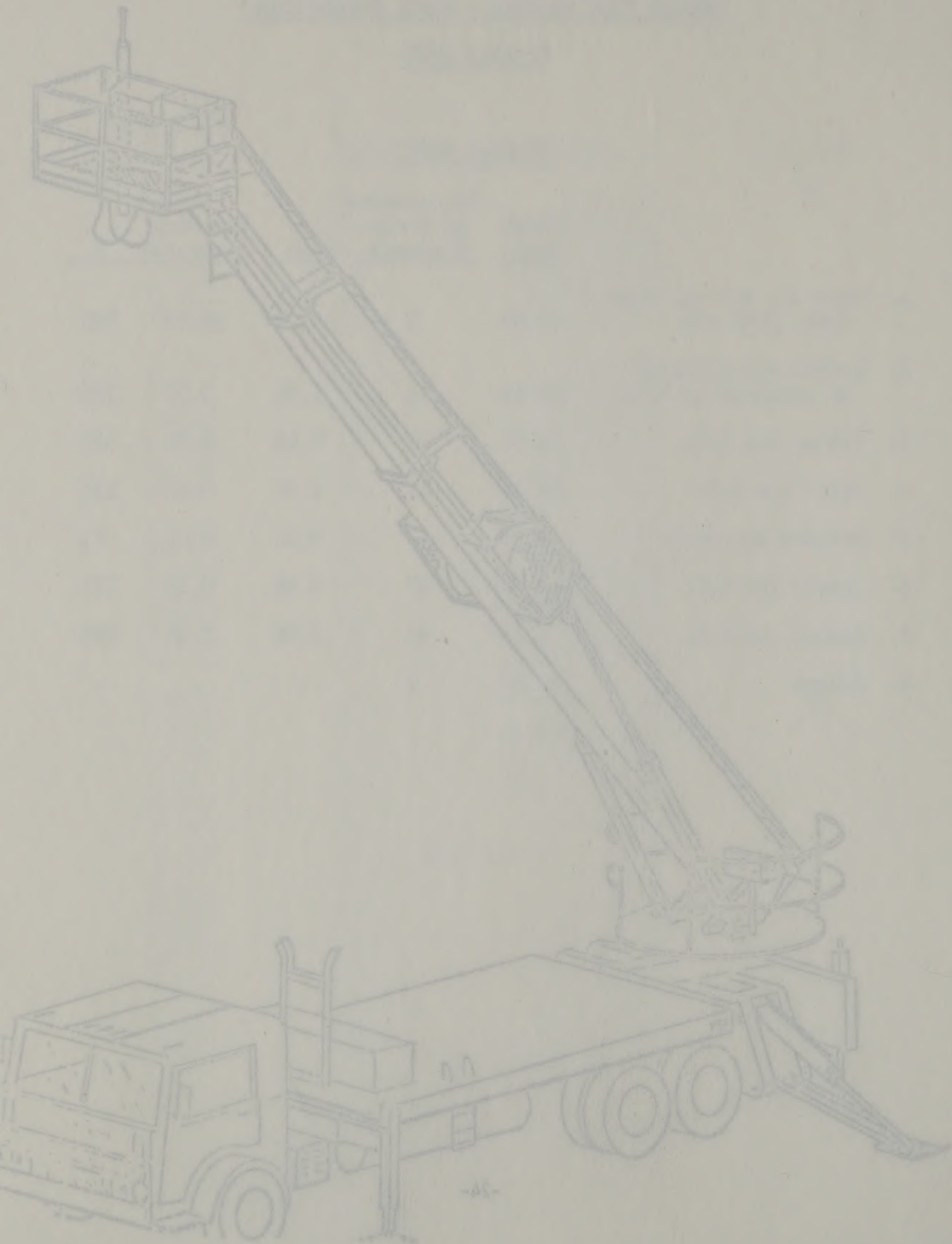


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PARAHO DEMONSTRATION PROJECT

MAN/MACHINE WORK STUDIES

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VENTILATION

October
1975

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PARADOXICAL INVESTIGATION PROJECT

MANUFACTURING WORK STUDIES

VENTILATION

October
1972

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MANMACHINE WORK STUDIES

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PROJECT LOCATION AND VENTILATION FUNCTION

PARAHO DEMONSTRATION PROJECT

MAN/MACHINE WORK STUDIES

Anvil Points Mine
Rifle, Colorado

October 1975

EQUIPMENT DESCRIPTION

PROJECT:

Work Studies - Ventilation System - time required in
expanding and moving the system.

DESCRIPTION:

Data collection on this function was directed to the time involved
to take down, move and install the various components comprising the
ventilation system.

PURPOSE:

To develop standard times for a commercial operation from actual
times observed in the pilot mine. TABLE I

AUTHOR:

	MOTOR H.P.	MANUFACTURER & RPM	CUBIC FEET OF AIR MOVED/MINUTE
72"	W. W. Moulton	Joy 4,400	100,000
36"	40 H.P.	Joy 3,450	Not Available
28"	15 H.P.	Joy 1,725	Not Available

BARABO INVESTIGATION PROJECT

MACHINERY WORK STUDIES

Avail Pointa Mine
Bille, Colorado

October 1975

PROJECT:

Work Studies - Ventilation System - time required in

expanding and moving the system.

DESCRIPTION:

Data collection on this fraction was directed to the time involved

to take down, move and install the various components comprising the

ventilation system.

PURPOSE:

To develop standard times for a commercial operation from actual

times observed in the pilot mine.

AUTHOR:

W. W. Hanson

PROJECT LOCATION AND VENTILATION FUNCTION

This industrial engineering project was performed at the Paraho Demonstration Project's Anvil Points Mine, near Rifle, Colorado. The mine utilizes room and pillar mining for the extraction of oil shale rock. With room dimensions of 55 feet wide and 40 feet high, an efficient ventilation system is needed.

EQUIPMENT DESCRIPTION

Ventilation in the Anvil Points Mine is accomplished by the use of fans, both permanently placed and mobile. The permanently placed fan is six feet in diameter and is installed approximately 800 feet from the Able Drift portal entrance (see diagram, page 8). The other two fans are mobile and are moved into working areas.

Table I indicates the size, horsepower of the motor, manufacturer and cubic feet of air moved per minute for each fan.

Equipment used in the process of moving the 72" fan included the roof bolting carrier, powder monkey carrier and the Hough 560 Pay Loader.

TABLE I

<u>DIAMETER</u>	<u>MOTOR H.P.</u>	<u>MANUFACTURER & RPM</u>		<u>CUBIC FEET OF AIR MOVED/MINUTE</u>
72"	75 H.P.	Joy	4,400	100,000
32"	40 H.P.	Joy	3,450	Not Available
28"	15 H.P.	Joy	1,725	Not Available

PROJECT LOCATION AND VENTILATION PROBLEM

This industrial engineering project was performed at the Parachu Demonstration Project's Aerial Portals Mine, near Rifle, Colorado. The mine utilizes room and pillar mining for the extraction of oil shale rock. With room dimensions of 55 feet wide and 40 feet high, an efficient ventilation system is needed.

EQUIPMENT DESCRIPTION

Ventilation in the Aerial Portals Mine is accomplished by the use of fans, both permanently placed and mobile. The permanently placed fan is six feet in diameter and is installed approximately 800 feet from the Aerial Drift portal entrance (see diagram, page 8). The other two fans are mobile and are moved into working areas.

Table I indicates the size, horsepower of the motor, manufacturer and cubic feet of air moved per minute for each fan.

Equipment used in the process of moving the 72" fan included the roof bolting carrier, power runway carrier and the Hough 560 Pay loader.

TABLE I

<u>DIAMETER</u>	<u>H.P.</u>	<u>MANUFACTURER & MIN.</u>	<u>CUBIC FEET OF AIR MOVED/minute</u>
72"	75 H.P.	Joy	4,400
32"	40 H.P.	Joy	3,450
28"	15 H.P.	Joy	1,725

CYCLE TIMES

Cycle times were taken when the six foot Joy fan was moved 150 feet further into Able Drift. Cycle times were taken for the following elements:

1. Unhook electricals and take down the fan;
2. Install roof bolts to hang the fan;
3. Hang the fan 150 feet from previous location;
4. String electrical cable to the fan;
5. Hang vent bag to the fan;
6. Hook up fan electricals.

ACTUAL WORK CYCLE

Ventilation System - 6 Men

CONDITIONS:

Floor - Smooth and Clean

Back - Smooth with Roof Bolts

POSSIBLE PRODUCTIVE WORK TIME:

(Assume 100% utilization of available time)

WORK TIME

Cycle times were taken when the six foot Joy fan was moved 150

feet further into the pit. Cycle times were taken for the following

elements:

1. Unhook electricals and take down the fan;
2. Install roof bolts to hang the fan;
3. Hang the fan 150 feet from previous location;
4. String electrical cable to the fan;
5. Hang vent bag to the fan;
6. Hook up fan electricals.

ACTUAL WORK CYCLE

Ventilation System - 6 Men

CRITICAL

Floor - Smooth and Clean
Back - Smooth with Roof Bolts

POSSIBLE PRODUCTIVE WORK TIME

(Assume 100% utilization of available time)

Allowances:

Travel to Mine	30 Minutes
Travel to Lunch	5 Minutes
Lunch	30 Minutes *
Return to Work	5 Minutes
Supervision	15 Minutes
Personal	15 Minutes
Travel from Mine	<u>30 Minutes</u>
	100 Minutes

* Not Paid and Not Included in Total.

Total Work Day - 8 hours or 480 minutes = 480 - 100 = 380 minutes
(possible productive work time)

Actual Work Times -	<u>August 14, 1975</u>	<u>August 15, 1975</u>
Starting Time	10:38 A.M.	8:10 A.M.
Finishing Time	6:02 P.M.	6:00 P.M.
Total Minutes Working Time	444 Minutes	590 Minutes

ACTUAL WORK CYCLE

August 14, 1975 - Five men worked a total of 729.22 man-minutes or 12.15 man-hours.

	<u>Two Men</u>
Unhook electricals and take down fan	63.55 Minutes
Tie Ventilation Bag Together (6 sections)	192.06 Minutes

	<u>One Man</u>
Install roof bolts to hang fan and vent bag	143.00 Minutes

Allowances:

Travel to Mine	30 Minutes
Travel to Lunch	5 Minutes
Lunch	30 Minutes *
Return to Work	5 Minutes
Supervision	15 Minutes
Personal	15 Minutes
Travel from Mine	30 Minutes
	100 Minutes

* Not Paid and Not Included in Total.

Total Work Day - 8 hours or 480 minutes = 480 - 100 = 380 minutes
(possible productive work time)

Actual Work Times -	August 14, 1975	August 15, 1975
Starting Time	10:38 A.M.	8:10 A.M.
Finishing Time	6:02 P.M.	6:00 P.M.
Total Minutes Working Time	444 Minutes	290 Minutes

ACTUAL WORK CYCLE

August 14, 1975 - Five men worked a total of 729.21 man-minutes or 12.15 man-hours.

Two Men

Unhook electrals and take down fan 63.55 Minutes
The Ventilation Bag Together (6 sections) 192.06 Minutes

One Man

Install roof bolts to hang fan and vent bag 143.00 Minutes

Lunch: 5.0 Minutes to lunch
 35.0 Lunch (30 Minutes not paid)
5.0 Minutes return to work

Total: 45.0 Minutes

443.61 Minutes

Minus (30 minute not paid lunch)

30.00 Minutes

413.61 Total Working
 Minutes

August 15, 1975 - Seven men worked a total of 2,223 man-minutes or
 37.05 man-hours.

Hang Fan Three Men
 230.00 Minutes

String up Electrical Cable Two Men
 79.00 Minutes

Hang Vent Bag Three Men
 240.00 Minutes

Hook up Electricals Two Men
 240.00 Minutes

Lunch: 5.0 Minutes to Lunch
 45.0 Minutes Lunch (30 minutes not paid)
5.0 Minutes Return to Work

Total: 55.0 Minutes

844.00 Minutes

Minus (30 minute lunch)

30.00 Minutes

Total Working Minutes

814.00

Total man-hours required to take down, move and install various components comprising the ventilation system are as follows:

August 14, 1975: 729.22 man-minutes = 12.15 man-hours

August 15, 1975: 2223.00 man-minutes = 37.05 man-hours

Total Man-Hours 49.20

System was moved 150 feet - $\frac{150 \text{ feet}}{49.20} = 3.05 \text{ feet per man-hour}$

BREAK OUT THREE ELEMENTS

These elements are: tie the vent bag together, roof bolt to hang vent bag and hang vent bag are as follows: (times are in man-minutes)

Tie vent bag together (6 sections)	384.12 Man-Minutes
Roof bolt to hang vent bag	143.00 Man-Minutes
Hang vent bag	<u>720.00 Man-Minutes</u>
	1247.12 Man-Minutes

$\frac{1247.12}{60} = 20.78 \text{ Man-Hours}$

$\frac{150 \text{ ft.}}{20.78} = 7.21 \text{ feet/man-hour to assemble vent bag sections, roof bolt to hang vent bag and hang vent bag.}$

PROJECTED WORK CYCLE

COMMERCIAL OPERATION

In projecting a work cycle for the moving of certain components of a ventilation system some important factors will have to be considered. A commercial size operation will require a trained crew with special equipment to keep the progress of the ventilation system in conjunction with mine development. In view of the immense size of an oil shale mine, the large tonnages of rock that will be handled and the vast amounts of

that that will exist it is suggested that an excess in the return air
requirements be relied upon to provide adequately clean air at the work
face. Also the choice of certain mine designs and sequences in operations
will aid in the development of an adequate ventilation system.
Colorado State Mining laws require an underground operation
using diesel powered equipment to supply 100 cubic feet of air per minute
for each diesel horsepower operating in the mine. In addition to the
above requirement, an additional 75 cubic feet of air per minute must
be supplied for every man working in the mine.

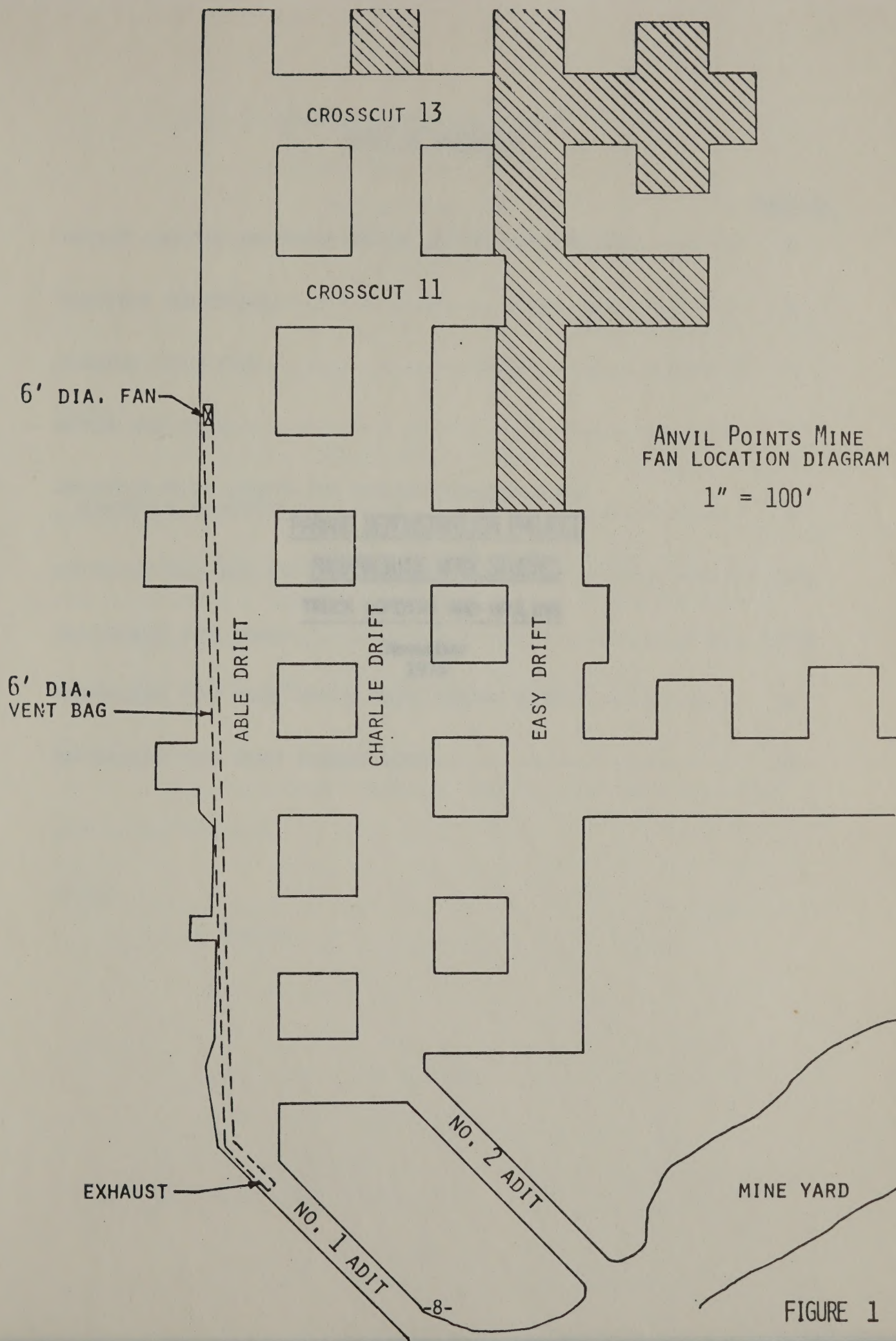


FIGURE 1

ANVIL POINTS MINE
FAN LOCATION DIAGRAM

1" = 100'

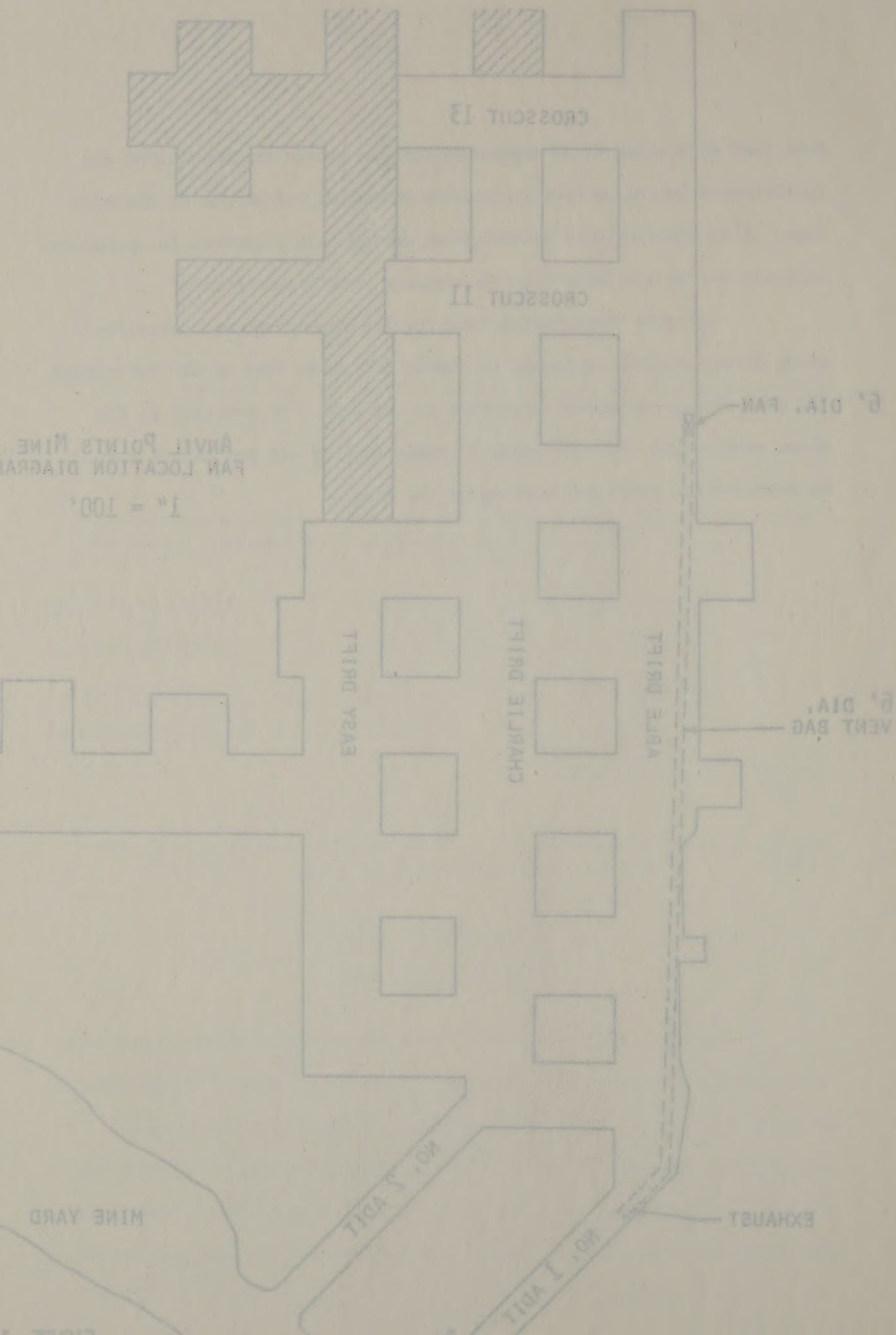


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PAVING INVESTIGATION PROJECT

WYNNACHIE WORK STUDIES

TRUCK LOADING AND HAULING

November
1975

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AFTER:

W. W. Moulton

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PARAHO DEMONSTRATION PROJECT

MAN/MACHINE WORK STUDIES

Anvil Points Mine
Rifle, Colorado

November 1975

PROJECT:

Work Studies - Truck Loading and Hauling

DESCRIPTION:

Work studies utilizing a break out of elemental times were used to calculate a standard cycle time for truck loading and hauling rock produced from one twenty foot round. The standard twenty foot round produces approximately 2,950 tons of oil shale rock.

PURPOSE:

Calculate a truck loading and hauling cycle for a commercial size mining operation.

AUTHOR:

W. W. Moulton

1. Dose the truck pile.
2. Load the bucket.
3. Back and turn towards truck.
4. Travel loaded towards truck.
5. Dump into truck.
6. Travel empty to rock pile.

PARADO DEMONSTRATION PROJECT

MAN/MACHINE WORK STUDIES

Anvil Pointe Mine

Rifle, Colorado

November 1975

PROJECT:

Work Studies - Truck Loading and Hauling

DESCRIPTION:

Work studies utilizing a break out of elemental times were used to calculate a standard cycle time for truck loading and hauling rock produced from one twenty foot round. The standard twenty foot round produces approximately 2,950 tons of oil shale rock.

PURPOSE:

Calculate a truck loading and hauling cycle for a commercial

size mining operation.

AUTHOR:

W. W. Moulton

PROJECT LOCATION AND TRUCK LOADING AND HAULING FUNCTION

This industrial engineering project was performed at the Paraho Demonstration Project's Anvil Points Mine near Rifle, Colorado. The mine utilizes room and pillar mining for the extraction of oil shale rock. Room dimensions are 55 feet wide by 40 feet high. Each round is designed to advance 20 feet and produce approximately 2,950 tons of oil shale rock.

EQUIPMENT DESCRIPTION

Truck loading is performed by a Hough 560 Payloader equipped with a 6.5 cubic yard bucket. Trucks are 50 ton International Payhaulers.

STANDARD CYCLE TIME

The truck loading and hauling function takes place after the charging and blasting function.

Standard cycle time is the computation of the total time required to load and haul a truckload of oil shale rock. Total time is the summation of elemental times derived from the timing of cycle elements. Cycle elements for the truck loading function are as follows:

1. Doze the muck pile.
2. Load the bucket.
3. Back and turn towards truck.
4. Travel loaded towards truck.
5. Dump into truck.
6. Travel empty to muck pile.

PROJECT LOCATION AND TRUCK LOADING AND HAULING FUNCTION

This industrial engineering project was performed at the Paraho Demonstration Project's Avoli Point Mine near Rifle, Colorado. The mine utilizes room and pillar mining for the extraction of oil shale rock. Room dimensions are 22 feet wide by 40 feet high. Each room is designed to advance 20 feet and produce approximately 2,950 tons of oil shale rock.

EQUIPMENT DESCRIPTION

Truck loading is performed by a Hough 560 Payloader equipped with a 6.5 cubic yard bucket. Trucks are 50 ton International Payhulders.

STANDARD CYCLE TIME

The truck loading and hauling function takes place after the charging and blasting function. Standard cycle time is the computation of the total time required to load and haul a truckload of oil shale rock. Total time is the summation of elemental times derived from the timing of cycle elements. Cycle elements for the truck loading function are as follows:

1. Dose the mark pile.
2. Load the bucket.
3. Back and turn towards truck.
4. Travel loaded towards truck.
5. Dump into truck.
6. Travel empty to mark pile.

The truck hauling function cycle time is the total time it takes a truck to make a round trip from the mine to the crusher stockpile. This time includes the loading function time and is listed on page 18. The mean, standard deviation and percent standard deviation are also on this page.

Standard industrial engineering procedures used in the truck loading and hauling analysis involved calculation of mean times, standard deviation and percent standard deviation.

In order to determine if a sufficient number of element cycles were recorded to allow a confidence level of 95% each element cycle was analyzed using the "t" test. This calculation is included on pages 6 to 11. The "t" test for truck hauling is on page 6.

The man/machine time chart, pages 12 to 18, is a step by step breakdown of cycle element times with a cumulative time summation. This chart is followed by a summary sheet, page 20 which shows the total time, mean, standard deviation and percent standard deviation for each cycle element.

ACTUAL WORK CYCLE

Truck Loading and Hauling

1. Loader (equipped with a 6.5 cubic yard bucket)
2. Trucks (50 ton rating)

CONDITIONS:

- Roads - in face (muck pile) area - irregular
- haulage roads in mine - good (smooth)
- haulage roads from mine portal to crusher - smooth with excessive grade

The truck hauling function cycle time is the total time it takes a truck to make a round trip from the mine to the crusher stockpile. This time includes the loading function time and is listed on page 18. The mean, standard deviation and percent standard deviation are also on this page.

Standard industrial engineering procedures used in the truck loading and hauling analysis involved calculation of mean times, standard deviation and percent standard deviation.

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The man/machine time chart, pages 12 to 18, is a step by step breakdown of cycle element times with a cumulative time summation. This chart is followed by a summary sheet, page 20 which shows the total time, mean, standard deviation and percent standard deviation for each cycle element.

ACTUAL WORK CYCLE

Truck Loading and Hauling

1. Loader (equipped with a 6.5 cubic yard bucket)
2. Trucks (50 ton rating)

CONDITIONS:

- Roads - in face (truck pile) area - irregular
- haulage roads in mine - good (smooth)
- haulage roads from mine portal to crusher - smooth with excessive grade

POSSIBLE PRODUCTIVE WORK TIME:

(Assume 100% utilization of available time)

Allowances:

Travel to Work	30 Minutes
Travel to Lunch	5 Minutes
Lunch	30 Minutes *
Return to Work	5 Minutes
Supervision	15 Minutes
Personal	15 Minutes
Travel from Mine	<u>30 Minutes</u>
	100 Minutes

* Not Paid and Not Included in Total.

Total Work Day - 8 hours or 480 minutes = 480 - 100 = 380 minutes
(possible productive work time)

CYCLE ELEMENT (TOTALS) FOR TRUCK LOADING:

These numbers are based on the timing of actual cycle elements; these times are for the loading of one bucket.

1. Doze the muck pile	.09 Minutes
2. Load bucket	.12 Minutes
3. Back and turn	.16 Minutes
4. Travel loaded	.17 Minutes
5. Dump into truck	.09 Minutes
6. Travel empty	<u>.09 Minutes</u>

0.72 Minutes

POSSIBLE PRODUCTIVE WORK TIME

(Assumes 100% utilization of available time)

Allowances:

Travel to Work	30 Minutes
Travel to Lunch	5 Minutes
Lunch	30 Minutes *
Return to Work	5 Minutes
Separated	15 Minutes
Personal	15 Minutes
Travel from Mine	30 Minutes
	<u>100 Minutes</u>

* Not Paid and Not Included in Total

Total Work Day - 8 hours or 480 minutes = 480 - 100 = 380 minutes
(possible productive work time)

CYCLE ELEMENT (TOTALS) FOR TRUCK LOADING

These numbers are based on the timing of actual cycle elements; these times are for the loading of one bucket.

1. Haul the rock pile	09 Minutes
2. Load bucket	12 Minutes
3. Back and turn	16 Minutes
4. Travel loaded	17 Minutes
5. Dump into truck	09 Minutes
6. Travel empty	<u>09 Minutes</u>
	0.72 Minutes

Truck Hauling

With a haulage road distance of 5.5 miles from the mine to the crusher stockpile it takes a truck 62.625 minutes to complete a round trip (including loading the truck)

Based on a 1.05 ton/cubic yard - approximately nine loader buckets are required to fill a truck. This equals 6.48 minutes.

$$\begin{array}{r} 62.625 \text{ Minutes (truck round trip)} \\ - \quad 6.48 \text{ Minutes (truck loading)} \\ \hline 56.145 \text{ Minutes (truck hauling time)} \end{array}$$

$$5.5 \text{ miles} = 29,040 \text{ feet} = 29.04 \text{ thousand feet} \quad \frac{56.145}{29.04} = 1.93 \text{ min./1000 feet}$$

$$1.93 \text{ min} \times 5.280 = 10.19 \text{ min./mile} \quad \frac{60.00 \text{ min/hr}}{10.19 \text{ min/mile}} = 5.89 \text{ MPH}$$

$$5.89 \text{ miles per hour (average) actual travel time} = 6.78 \text{ loads per 380 minutes per truck}$$

$$= 13.56 \text{ loads per work day}$$

$$\text{Actual Haulage} = 12 \text{ loads per work day}$$

PROJECTED TRUCK LOADING AND HAULING PROCEDURE FOR A COMMERCIAL OPERATION

In a commercial operation truck loading (using comparable equipment) will be done in approximately the same amount of time as actually timed for this report. Truck hauling will be cut down with respect to distance traveled. Trucks will not be hauling up and down the hill from the mine to the crusher stockpile. Truck haulage in a commercial operation will be from the working area in the mine to a crusher stockpile just outside the mine portal.

Truck Hauling

With a haulage road distance of 2.5 miles from the mine to the crusher stockpile it takes a truck 62.625 minutes to complete a round trip (including loading the truck)

Based on a 1.02 cubic yard - approximately nine loader buckets are required to fill a truck. This equals 6.48 minutes.
62.625 Minutes (truck round trip)
- 6.48 Minutes (truck loading)
56.145 Minutes (truck hauling time)

2.5 miles = 29,040 feet - 29.04 thousand feet $56.145 \div 1.93 \text{ min./1000 feet} = 29.04$
 $60.00 \text{ min/hr} \div 1.93 \text{ min/mile} = 31.09 \text{ MPH}$
2.89 miles per hour (average) actual travel time = 6.78 loads per 380 minutes per truck
= 13.56 loads per work day
Actual Haulage = 12 loads per work day

PROJECTED TRUCK HAULING AND HAULING PROCEDURE FOR A COMMERCIAL OPERATION

In a commercial operation truck loading (using comparable equipment) will be done in approximately the same amount of time as actually timed for this report. Truck hauling will be cut down with respect to distance traveled. Trucks will not be hauling up and down the hill from the mine to the crusher stockpile. Truck haulage in a commercial operation will be from the working area in the mine to a crusher stockpile just outside the mine portal.

TRUCK HAULING

Calculations to estimate true mean (M) from sample data.

$$\sum x = 2004$$

$$N = 32$$

$$\bar{x} = 62.625$$

$$\sum x^2 = 128,420$$

$$S(x) = \sqrt{\frac{\sum x^2 - \bar{x} \sum x}{N-1}}$$

$$S(x) = \sqrt{\frac{128,420 - 62.625 (2004)}{32-1}}$$

$$S(x) = \sqrt{\frac{128,420 - 125,500}{31}} = \sqrt{\frac{2,920}{31}} = \sqrt{94.193} = 9.705$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{9.705}{\sqrt{32}} = \frac{9.705}{5.656} = 1.715$$

M @ 95% Confidence Level

$$M = \bar{x} \pm T_{0.05} S(\bar{x})$$

$$M = 62.625 \pm 2.0378 (1.715)$$

$$M = 62.625 \pm 3.49 \text{ minutes}$$

TRUCK HAULING

Calculations to estimate true mean (Q) from sample data.

$$\begin{aligned} \sum x &= 128,420 \\ \bar{x} &= 62.622 \\ n &= 32 \\ \sum x^2 &= 2004 \end{aligned}$$

$$\begin{aligned} s(x) &= \sqrt{\frac{\sum x^2 - \frac{(\sum x)^2}{n}}{n-1}} \\ s(x) &= \sqrt{\frac{128,420 - \frac{(128,420)^2}{32}}{32-1}} \\ s(x) &= \sqrt{\frac{128,420 - 125,200}{31}} = \sqrt{\frac{3,220}{31}} = \sqrt{103.87} = 10.192 \end{aligned}$$

$$s(x) = \frac{s(x)}{\sqrt{n}}$$

$$s(x) = \frac{10.192}{\sqrt{32}} = \frac{10.192}{5.656} = 1.775$$

95% Confidence Level

$$n = 32 \quad t = 0.05 \quad s(x)$$

$$M = 62.622 \pm 1.775 (1.775)$$

$$M = 62.622 \pm 3.149 \text{ minutes}$$

TRUCK LOADING - DOZE THE MUCK PILE

Calculations to estimate true mean (M) from sample data.

$$\sum x = 3.11$$

$$N = 33$$

$$\bar{x} = .0939$$

$$\sum x^2 = .3001$$

$$S(x) = \sqrt{\frac{\sum x^2 - \bar{x} \sum x}{N-1}}$$

$$S(x) = \sqrt{\frac{.3001 - .0939 (3.11)}{33-1}}$$

$$S(x) = \sqrt{\frac{.3001 - .2920}{32}} = \sqrt{\frac{.0081}{32}} = \sqrt{.00025} = .0159$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{0.0159}{\sqrt{33}} = \frac{0.0159}{5.7445} = .0027$$

M @ 95% Confidence Level

$$M = \bar{x} \pm T_{0.05} S(\bar{x})$$

$$M = .0939 \pm 2.0399 (.0027)$$

$$M = .0939 \pm .0055 \text{ minutes}$$

TRUCK LOADING - DOZE THE MUCK PILE

Calculations to estimate true mean (μ) from sample data.

$$\begin{aligned} s_x &= 3.11 \\ N &= 33 \\ \bar{x} &= .0939 \\ s_x^2 &= .3001 \end{aligned}$$

$$\begin{aligned} s(x) &= \sqrt{\frac{s_x^2}{N-1}} = \sqrt{\frac{.3001}{33-1}} = \sqrt{\frac{.3001}{32}} = \sqrt{\frac{.009378}{32}} = \sqrt{.000293} = .0172 \\ s(x) &= \sqrt{\frac{s_x^2}{N}} = \sqrt{\frac{.3001}{33}} = \sqrt{\frac{.009091}{33}} = \sqrt{.000275} = .0166 \end{aligned}$$

$$\begin{aligned} s(x) &= \frac{s(x)}{\sqrt{N}} \\ s(x) &= \frac{.0172}{\sqrt{33}} = \frac{.0172}{5.7446} = .00298 \end{aligned}$$

95% Confidence Level

$$\begin{aligned} N &= Z^2 \cdot \frac{s(x)}{E} \\ N &= (1.96)^2 \cdot \frac{.00298}{.0025} \\ N &= 3.92 \cdot 1.192 = 4.67264 \end{aligned}$$

TRUCK LOADING - LOAD THE BUCKET

Calculations to estimate true mean (M) from sample data.

$$\sum x = 4.91$$

$$N = 40$$

$$\bar{x} = 0.12275$$

$$\sum x^2 = .6166$$

$$S(x) = \sqrt{\frac{\sum x^2 - \bar{x} \sum x}{N-1}}$$

$$S(x) = \sqrt{\frac{.6166 - .12275 (4.91)}{40-1}}$$

$$S(x) = \sqrt{\frac{.6166 - .6027}{39}} = \sqrt{\frac{.0139}{39}} = \sqrt{.0004} = .02$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{.02}{\sqrt{40}} = \frac{.02}{6.3245} = .003$$

M @ 95% Confidence Level

$$M = \bar{x} \pm T_{0.05} S(\bar{x})$$

$$M = .122 \pm 2.021 (.003)$$

$$M = .122 \pm .006 \text{ minutes}$$

TRUCK LOADING - LOAD THE BUCKET

Calculations to estimate true mean (μ) from sample data.

$$\begin{aligned} s_x &= 4.91 \\ n &= 40 \\ \bar{x} &= 0.1237 \\ s_x^2 &= .0166 \end{aligned}$$

$$\begin{aligned} s(x) &= \sqrt{\frac{s_x^2 - \bar{x} s_x}{n-1}} \\ s(x) &= \sqrt{\frac{.0166 - .1237(4.91)}{40-1}} \\ s(x) &= \sqrt{\frac{.0166 - .6077}{39}} = \sqrt{\frac{.0139}{39}} = \sqrt{.0004} = .02 \end{aligned}$$

$$\begin{aligned} s(x) &= \frac{s(x)}{\sqrt{n}} \\ s(x) &= \frac{.02}{\sqrt{40}} = \frac{.02}{6.3246} = .003 \end{aligned}$$

$M \pm 95\%$ Confidence Level

$$\begin{aligned} M &= \bar{x} \pm 0.05 s(x) \\ M &= .1237 \pm 0.015 \\ M &= .123 \pm .006 \text{ minutes} \end{aligned}$$

TRUCK LOADING - BACK AND TURN

Calculations to estimate true mean (M) from sample data.

$$\sum x = 5.60$$

$$N = 36$$

$$\bar{x} = .15555$$

$$\sum x^2 = .9135$$

$$S(x) = \sqrt{\frac{\sum x^2 - \bar{x} \sum x}{N-1}}$$

$$S(x) = \sqrt{\frac{.9135 - .1555 (5.60)}{36-1}}$$

$$S(x) = \sqrt{\frac{.9135 - .8710}{35}} = \sqrt{\frac{.0425}{35}} = \sqrt{.00121} = .034846$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{.034846}{\sqrt{36}} = \frac{.034846}{6} = .0058$$

M @ 95% Confidence Level

$$M = \bar{x} \pm T_{0.05} S(\bar{x})$$

$$M = .15555 \pm 2.0294 (.0058)$$

$$M = .15555 \pm .013 \text{ minutes}$$

TRUCK LOADING - BACK AND FORTH

Calculations to estimate true mean (μ) from sample data.

$$\begin{aligned} \bar{x} &= 2.60 \\ n &= 36 \\ \bar{x} &= 1.1555 \\ s_x &= .9135 \end{aligned}$$

$$\begin{aligned} s(x) &= \sqrt{\frac{s_x^2 - \bar{x}^2}{n-1}} \\ s(x) &= \sqrt{\frac{.9135^2 - 1.1555^2}{36-1}} \\ s(x) &= \sqrt{\frac{.9135^2 - .8710}{35}} = \sqrt{\frac{.0425}{35}} = \sqrt{.00121} = .034846 \end{aligned}$$

$$\begin{aligned} s(x) &= \frac{s(x)}{\sqrt{n}} \\ s(x) &= \frac{.034846}{\sqrt{36}} = \frac{.034846}{6} = .0058 \end{aligned}$$

95% Confidence Level

$$\begin{aligned} M &= \bar{x} \pm 0.05 s(x) \\ M &= 1.1555 \pm 0.0294 (.0058) \\ M &= 1.1555 \pm 0.013 \text{ minutes} \end{aligned}$$

TRUCK LOADING - DUMP THE BUCKET

Calculations to estimate true mean (M) from sample data.

$$\sum x = 3.46$$

$$N = 38$$

$$\bar{x} = .0910$$

$$\sum x^2 = .3666$$

$$S(x) = \sqrt{\frac{\sum x^2 - \bar{x} \sum x}{N-1}}$$

$$S(x) = \sqrt{\frac{.3666 - (.0910) 3.46}{38-1}}$$

$$S(x) = \sqrt{\frac{.3666 - .3148}{37}} = \sqrt{\frac{.0518}{37}} = \sqrt{.0014} = .0374$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{.0374}{\sqrt{38}} = \frac{.0374}{6.164} = .006$$

M @ 95% Confidence Level

$$M = \bar{x} \pm T_{0.05} S(\bar{x})$$

$$M = .091 \pm 2.0252 (.006)$$

$$M = .091 \pm .012 \text{ minutes}$$

TRUCK LOADING - DUMP THE BUCKET

Calculations to estimate true mean (μ) from sample data.

$$\begin{aligned} \bar{x} &= 3.46 \\ n &= 38 \\ \bar{x} &= .0910 \\ s_x^2 &= .3666 \end{aligned}$$

$$\begin{aligned} s(x) &= \sqrt{\frac{s_x^2 - \bar{x}^2}{n-1}} \\ s(x) &= \sqrt{\frac{.3666 - (.0910)^2}{38-1}} \\ s(x) &= \sqrt{\frac{.3666 - .0828}{37}} = \sqrt{\frac{.2838}{37}} = \sqrt{.00767} = .0276 \end{aligned}$$

$$\begin{aligned} s(x) &= \frac{s(x)}{\sqrt{n}} \\ s(x) &= \frac{.0276}{\sqrt{38}} = \frac{.0276}{6.164} = .00448 \end{aligned}$$

95% Confidence Level

$n = 38$ (D.F. 37)

$t = 2.026$ (from table)

$M = .091 \pm .012$ minutes

TRUCK LOADING - TRAVEL EMPTY

Calculations to estimate true mean (M) from sample data.

$$s_x = 2.85$$

$$N = 32$$

$$\bar{x} = .089$$

$$s_x^2 = .2629$$

$$S(x) = \sqrt{\frac{s_x^2 - \bar{x} s_x}{N-1}}$$

$$S(x) = \sqrt{\frac{.2629 - .089 (2.85)}{32-1}}$$

$$S(x) = \sqrt{\frac{.2629 - .2536}{31}} = \sqrt{\frac{.0093}{31}} = \sqrt{.0003} = .0173$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{.0173}{\sqrt{32}} = \frac{.0173}{5.6568} = .003$$

M @ 95% Confidence Level

$$M = \bar{x} \pm T_{0.05} S(\bar{x})$$

$$M = .089 \pm 2.6378 (.003)$$

$$M = .089 \pm .006 \text{ minutes}$$

TRUCK LOADING - TRAWL FIFTY

Calculations to estimate true mean (μ) from sample data.

$$\begin{aligned} s_x &= 2.85 \\ n &= 35 \\ \bar{x} &= .089 \\ s_x^2 &= .2639 \end{aligned}$$

$$\begin{aligned} s(x) &= \sqrt{\frac{s_x^2 - \bar{x}^2}{n-1}} \\ s(x) &= \sqrt{\frac{.2639 - (.089)^2}{35-1}} \\ s(x) &= \sqrt{\frac{.2639 - .0079}{31}} = \sqrt{\frac{.0091}{31}} = \sqrt{.0003} = .0173 \end{aligned}$$

$$\begin{aligned} s(x) &= \frac{s(x)}{\sqrt{n}} \\ s(x) &= \frac{.0173}{\sqrt{31}} = \frac{.0173}{5.568} = .003 \end{aligned}$$

M @ 95% Confidence Level
 $M = \bar{x} \pm t_{0.05} s(x)$
 $M = .089 \pm 2.0378 (.003)$
 $M = .089 \pm .006$ minutes

MAN/MACHINE TIME CHART

Loading and Hauling - Anvil Points Mine

November 1975

	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
	Doze	.07	.07
	Load	.11	.18
	Back and Turn	.08	.26
	Travel Loaded	.14	.40
1	Dump	.07	.47
	Travel Empty	.06	.53
	Doze	.08	.61
	Load	.12	.73
	Back and Turn	.14	.87
	Travel Loaded	.16	1.03
2	Dump	.09	1.12
	Travel Empty	.08	1.20
	Doze	.10	1.30
	Load	.11	1.41
	Back and Turn	.14	1.55
	Travel Loaded	.16	1.71
3	Dump	.18	1.89
	Travel Empty	.12	2.01
	Doze	-	2.01
	Load	.12	2.13
	Back and Turn	-	2.13
	Travel Loaded	.17	2.30
4	Dump	.17	2.47
	Travel Empty	-	2.47
	Doze	.06	2.53
	Load	.11	2.64
	Back and Turn	.12	2.76
	Travel Loaded	.18	2.94
5	Dump	.04	2.98
	Travel Empty	.08	3.06
	Doze	.08	3.14
	Load	.13	3.27
	Back and Turn	.16	3.43
	Travel Loaded	.12	3.55
6	Dump	.06	3.61
	Travel Empty	.05	3.66
	Doze	.08	3.74
	Load	.14	3.88
	Back and Turn	.11	3.99
	Travel Loaded	.16	4.15

MAN/MACHINE TIME CHART

Loading and Hauling - Anvil Point Mine

November 1975

CUMULATIVE TIME	TIME	ELEMENT
07	07	Dose
18	11	Load
26	08	Back and Turn
40	14	Travel Loaded
47	07	Drap
53	06	Travel Empty
61	08	Dose
73	12	Load
87	14	Back and Turn
1 03	16	Travel Loaded
1 12	09	Drap
1 20	08	Travel Empty
1 30	10	Dose
1 41	11	Load
1 52	14	Back and Turn
1 71	16	Travel Loaded
1 89	18	Drap
2 01	12	Travel Empty
2 01	-	Dose
2 13	12	Load
2 13	-	Back and Turn
2 30	17	Travel Loaded
2 47	17	Drap
2 47	-	Travel Empty
2 53	06	Dose
2 64	11	Load
2 76	12	Back and Turn
2 94	18	Travel Loaded
2 98	04	Drap
3 06	08	Travel Empty
3 14	08	Dose
3 27	13	Load
3 43	16	Back and Turn
3 52	12	Travel Loaded
3 61	06	Drap
3 66	03	Travel Empty
3 74	08	Dose
3 88	14	Load
3 99	11	Back and Turn
4 12	16	Travel Loaded

MAN/MACHINE TIME CHARTLoading and Hauling - Anvil Points MineNovember 1975

	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
7	Dump	.07	4.22
	Travel Empty	.07	4.29
	Doze	.11	4.40
	Load	.09	4.49
	Back and Turn	.16	4.65
	Travel Loaded	.21	4.86
8	Dump	.07	4.93
	Travel Empty	.08	5.01
	Doze	.10	5.11
	Load	.13	5.24
	Back and Turn	.16	5.40
	Travel Loaded	.20	5.60
9	Dump	.07	5.67
	Travel Empty	.13	5.80
	Doze	.11	5.91
	Load	.13	6.04
	Back and Turn	.12	6.16
	Travel Loaded	.16	6.32
10	Dump	.09	6.41
	Travel Empty	.08	6.49
	Doze	.11	6.60
	Load	.08	6.68
	Back and Turn	.14	6.82
	Travel Loaded	.19	7.01
11	Dump	.10	7.11
	Travel Empty	-	7.11
	Doze	.11	7.22
	Load	.14	7.36
	Back and Turn	.24	7.60
	Travel Loaded	.21	7.81
12	Dump	.06	7.87
	Travel Empty	.12	7.99
	Doze	.10	8.09
	Load	.10	8.19
	Back and Turn	.18	8.37
	Travel Loaded	.12	8.49

MAN/MACHINE TIME CHART

Loading and Handling - Anvil Point Mine

November 1975

CUMULATIVE TIME	TIME	ELEMENT	
4.23	07	Drop	7
4.29	07	Travel Empty	
4.40	11	Dose	
4.49	09	Load	
4.63	16	Back and Turn	
4.86	21	Travel Loaded	
4.93	07	Drop	8
5.01	08	Travel Empty	
5.11	10	Dose	
5.24	13	Load	
5.40	16	Back and Turn	
5.60	20	Travel Loaded	
5.67	07	Drop	9
5.80	13	Travel Empty	
5.91	11	Dose	
6.06	13	Load	
6.16	13	Back and Turn	
6.32	16	Travel Loaded	
6.41	09	Drop	10
6.49	08	Travel Empty	
6.60	11	Dose	
6.68	08	Load	
6.83	14	Back and Turn	
7.01	19	Travel Loaded	
7.11	10	Drop	11
7.11	-	Travel Empty	
7.23	11	Dose	
7.36	14	Load	
7.60	24	Back and Turn	
7.81	21	Travel Loaded	
7.87	06	Drop	12
7.99	13	Travel Empty	
8.09	10	Dose	
8.19	10	Load	
8.37	18	Back and Turn	
8.48	13	Travel Loaded	

MAN/MACHINE TIME CHARTLoading and Hauling - Anvil Points MineNovember 1975

	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
13	Dump	.06	8.55
	Travel Empty	.08	8.63
	Doze	.08	8.71
	Load	.13	8.84
	Back and Turn	-	8.84
	Travel Loaded	-	8.84
14	Dump	.08	8.92
	Travel Empty	.11	9.03
	Doze	.09	9.12
	Load	.12	9.24
	Back and Turn	.17	9.41
	Travel Loaded	.16	9.57
15	Dump	.07	9.64
	Travel Empty	.09	9.73
	Doze	.11	9.84
	Load	.17	10.01
	Back and Turn	.18	10.19
	Travel Loaded	.12	10.31
16	Dump	.09	10.40
	Travel Empty	.09	10.49
	Doze	.08	10.57
	Load	.14	10.71
	Back and Turn	.21	10.92
	Travel Loaded	.15	11.07
17	Dump	.11	11.18
	Travel Empty	.09	11.27
	Doze	.12	11.39
	Load	.14	11.53
	Back and Turn	.19	11.72
	Travel Loaded	.19	11.91
18	Dump	.22	12.13
	Travel Empty	-	12.13
	Doze	.06	12.19
	Load	.11	12.30
	Back and Turn	.11	12.41
	Travel Loaded	.14	12.55

MANUACHINE TIME CHART

Loading and Hauling - Anvil Point Mine

November 1975

CUMULATIVE TIME	TIME	ELEMENT	
8.55	06	Drop	13
8.53	08	Travel Empty	
8.71	08	Dump	
8.54	13	Load	
8.54	-	Back and Turn	
8.54	-	Travel Loaded	
8.55	08	Drop	14
9.03	11	Travel Empty	
9.12	09	Dump	
9.24	12	Load	
9.41	17	Back and Turn	
9.57	16	Travel Loaded	
9.54	07	Drop	15
9.73	09	Travel Empty	
9.84	11	Dump	
10.01	17	Load	
10.19	18	Back and Turn	
10.31	12	Travel Loaded	
10.40	09	Drop	16
10.49	09	Travel Empty	
10.57	08	Dump	
10.71	14	Load	
10.92	21	Back and Turn	
11.07	12	Travel Loaded	
11.18	11	Drop	17
11.27	09	Travel Empty	
11.39	12	Dump	
11.53	14	Load	
11.75	19	Back and Turn	
11.91	19	Travel Loaded	
12.13	22	Drop	18
12.13	-	Travel Empty	
12.19	06	Dump	
12.30	11	Load	
12.41	11	Back and Turn	
12.52	14	Travel Loaded	

MAN/MACHINE TIME CHART

Loading and Hauling - Anvil Points Mine

November 1975

	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
19	Dump	.06	12.61
	Travel Empty	.09	12.70
	Doze	.09	12.79
	Load	.11	12.90
	Back and Turn	.09	12.99
	Travel Loaded	.19	13.18
20	Dump	.08	13.26
	Travel Empty	.10	13.36
	Doze	.09	13.45
	Load	.14	13.59
	Back and Turn	.13	13.72
	Travel Loaded	.17	13.89
21	Dump	.08	13.97
	Travel Empty	.08	14.05
	Doze	.09	14.14
	Load	.13	14.27
	Back and Turn	.13	14.40
	Travel Loaded	.19	14.59
22	Dump	.09	14.68
	Travel Empty	.09	14.77
	Doze	.07	14.84
	Load	.12	14.96
	Back and Turn	.11	15.07
	Travel Loaded	.22	15.29
23	Dump	.14	15.43
	Travel Empty	.09	15.52
	Doze	-	15.52
	Load	.11	15.63
	Back and Turn	.17	15.80
	Travel Loaded	-	15.80
24	Dump	.08	15.88
	Travel Empty	.09	15.97
	Doze	-	15.97
	Load	.11	16.08
	Back and Turn	.17	16.25
	Travel Loaded	-	16.25

MANUACHINE TIME CHART

loading and hauling - Arvill Pointe Mine

November 1975

CUMULATIVE TIME	TIME	ELEMENT	
12.61	06	Dump	19
12.70	09	Travel Empty	
12.79	09	Boze	
12.90	11	Load	
12.99	09	Back and Turn	
13.18	19	Travel Loaded	
13.36	08	Dump	20
13.36	10	Travel Empty	
13.45	09	Boze	
13.59	14	Load	
13.75	13	Back and Turn	
13.89	17	Travel Loaded	
13.97	08	Dump	21
14.05	08	Travel Empty	
14.14	09	Boze	
14.27	13	Load	
14.40	13	Back and Turn	
14.59	19	Travel Loaded	
14.68	09	Dump	22
14.77	09	Travel Empty	
14.84	07	Boze	
14.96	12	Load	
15.07	11	Back and Turn	
15.29	22	Travel Loaded	
15.43	14	Dump	23
15.52	09	Travel Empty	
15.52	-	Boze	
15.63	11	Load	
15.80	17	Back and Turn	
15.80	-	Travel Loaded	
15.88	08	Dump	24
15.97	09	Travel Empty	
15.97	-	Boze	
16.08	11	Load	
16.25	17	Back and Turn	
16.25	-	Travel Loaded	

MAN/MACHINE TIME CHART

Loading and Hauling - Anvil Points Mine

November 1975

	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
25	Dump	.08	16.33
	Travel Empty	.09	16.42
	Doze	-	16.42
	Load	.08	16.50
	Back and Turn	.16	16.66
	Travel Loaded	.16	16.82
26	Dump	.07	16.89
	Travel Empty	.08	16.97
	Doze	.11	17.08
	Load	.15	17.23
	Back and Turn	.19	17.42
	Travel Loaded	.11	17.53
27	Dump	.07	17.60
	Travel Empty	.07	17.67
	Doze	.10	17.77
	Load	.16	17.93
	Back and Turn	.17	18.10
	Travel Loaded	.11	18.21
28	Dump	.08	18.29
	Travel Empty	.10	18.39
	Doze	.11	18.50
	Load	.13	18.63
	Back and Turn	.17	18.80
	Travel Loaded	.10	18.90
29	Dump	.09	18.99
	Travel Empty	.09	19.08
	Doze	.11	19.19
	Load	.14	19.33
	Back and Turn	.21	19.54
	Travel Loaded	.13	19.67
30	Dump	.10	19.77
	Travel Empty	.10	19.87
	Doze	.11	19.98
	Load	.16	20.14
	Back and Turn	-	20.14
	Travel Loaded	.18	20.32
31	Dump	-	20.32
	Travel Empty	-	20.32
	Doze	.07	20.39
	Load	.13	20.52
	Back and Turn	.16	20.68
	Travel Loaded	.16	20.84

MINING TIME CHART

Location and Mining - Arrol Potash Mine

November 1975

CUMULATIVE TIME	TIME	EVENT	
16.33	08	Drop	29
16.42	09	Travel Empty	
16.43	-	Done	
16.50	08	Load	
16.58	16	Back and Turn	
16.58	16	Travel Loaded	
16.59	07	Drop	28
16.57	08	Travel Empty	
17.08	11	Done	
17.23	15	Load	
17.42	19	Back and Turn	
17.53	11	Travel Loaded	
17.50	07	Drop	27
17.57	07	Travel Empty	
17.71	10	Done	
17.93	16	Load	
18.10	17	Back and Turn	
18.21	11	Travel Loaded	
18.29	08	Drop	26
18.39	10	Travel Empty	
18.50	11	Done	
18.53	13	Load	
18.50	17	Back and Turn	
18.90	10	Travel Loaded	
18.99	09	Drop	25
19.08	09	Travel Empty	
19.19	11	Done	
19.33	14	Load	
19.54	21	Back and Turn	
19.57	13	Travel Loaded	
19.77	10	Drop	20
19.87	10	Travel Empty	
19.98	11	Done	
20.14	16	Load	
20.14	-	Back and Turn	
20.15	18	Travel Loaded	
20.32	-	Drop	21
20.32	-	Travel Empty	
20.39	07	Done	
20.52	13	Load	
20.58	16	Back and Turn	
20.54	16	Travel Loaded	

MAN/MACHINE TIME CHART

Loading and Hauling - Anvil Points Mine

November 1975

	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
32	Dump	.08	20.92
	Travel Empty	.07	20.99
	Doze	.11	21.10
	Load	.12	21.22
	Back and Turn	.16	21.38
	Travel Loaded	.14	21.52
33	Dump	.06	21.58
	Travel Empty	.08	21.66
	Doze	.10	21.76
	Load	.12	21.88
	Back and Turn	.15	22.03
	Travel Loaded	.17	22.20
34	Dump	.07	22.27
	Travel Empty	.09	22.36
	Doze	-	22.36
	Load	.13	22.49
	Back and Turn	.17	22.66
	Travel Loaded	.12	22.78
35	Dump	.07	22.85
	Travel Empty	-	22.85
	Doze	.11	22.96
	Load	.11	23.07
	Back and Turn	.19	23.26
	Travel Loaded	.18	23.44
36	Dump	.11	23.55
	Travel Empty	-	23.55
	Doze	-	23.55
	Load	.12	23.67
	Back and Turn	.18	23.85
	Travel Loaded	.21	24.06
37	Dump	.11	24.17
	Travel Empty	.10	24.27
	Doze	.12	24.39
	Load	.10	24.49
	Back and Turn	.11	24.60
	Travel Loaded	.22	24.82

MANUACHINE TIME CHART

loading and hauling - Arvill Pointe Mass

November 1972

CUMULATIVE TIME	TIME	ELEMENT	
20.92	08	Dump	32
20.99	07	Travel Empty	
21.10	11	Dose	
21.22	12	Load	
21.38	16	Back and Turn	
21.52	14	Travel Loaded	
21.58	06	Dump	33
21.66	08	Travel Empty	
21.76	10	Dose	
21.88	12	Load	
22.02	14	Back and Turn	
22.20	17	Travel Loaded	
22.27	07	Dump	34
22.36	09	Travel Empty	
22.36	-	Dose	
22.49	13	Load	
22.66	17	Back and Turn	
22.78	12	Travel Loaded	
22.82	07	Dump	35
22.82	-	Travel Empty	
22.96	11	Dose	
23.07	11	Load	
23.26	19	Back and Turn	
23.44	18	Travel Loaded	
23.52	11	Dump	36
23.52	-	Travel Empty	
23.52	-	Dose	
23.67	15	Load	
23.82	18	Back and Turn	
24.06	24	Travel Loaded	
24.17	11	Dump	37
24.27	10	Travel Empty	
24.39	12	Dose	
24.49	10	Load	
24.60	11	Back and Turn	
24.82	22	Travel Loaded	

MAN/MACHINE TIME CHART

Loading and Hauling - Anvil Points Mine

November 1975

	<u>ELEMENT</u>	<u>TIME</u>	<u>CUMULATIVE TIME</u>
38	Dump	.16	24.98
	Travel Empty	.11	25.09
	Doze	-	25.09
	Load	.09	25.18
	Back and Turn	.17	25.35
	Travel Loaded	.23	25.58
39	Dump	.08	25.66
	Travel Empty	-	25.66
	Doze	.06	25.72
	Load	.13	25.85
	Back and Turn	-	25.85
	Travel Loaded	.20	26.05
40	Dump	-	26.05
	Travel Empty	-	26.05

MAN/MACHINE TIME CHART

Actual Truck Hauling Times (Round Trip) From Mine to Crusher Stockpile

All Times in Minutes

53 Minutes	60 Minutes	60 Minutes
78 Minutes	56 Minutes	66 Minutes
81 Minutes	60 Minutes	51 Minutes
60 Minutes	53 Minutes	68 Minutes
71 Minutes	52 Minutes	
65 Minutes	55 Minutes	
90 Minutes	58 Minutes	
51 Minutes	56 Minutes	
72 Minutes	60 Minutes	
74 Minutes	60 Minutes	
81 Minutes	60 Minutes	
54 Minutes	63 Minutes	
56 Minutes	61 Minutes	
60 Minutes	59 Minutes	

SUMMARY

<u>Total Time</u>	<u>Occurrence</u>	<u>Mean</u>	<u>Standard Deviation</u>	<u>Per Cent Standard Deviation</u>
2,004.00	32	62.625	9.70	15%

MAN/MACHINE TIME CHART

Loading and Hauling - Anvil Points Mine

November 1975

SUMMARY SHEET

<u>Element</u>	<u>Total Time</u>	<u>Occurrences of Cycle Elements</u>	<u>Mean</u>	<u>Standard Deviation</u>	<u>Per Cent Standard Deviation</u>
1. Doze	3.11	33	.09	.02	19%
2. Load	4.91	40	.12	.02	16%
3. Back and Turn	5.60	36	.16	.04	22%
4. Travel Loaded	6.13	37	.17	.03	21%
5. Dump	3.46	38	.09	.04	41%
6. Travel Empty	2.84	32	.09	.02	19%
	<hr/> 26.05				

MANUFACTURING THE CYCLE

loading and handling - April 1975

November 1975

SUMMARY SHEET

Element	Total Time	Operations of Cycle Elements	Mean	Standard Deviation	Per Cent Standard Deviation
1. Dose	3.11	33	.09	.03	19%
2. Load	4.91	40	.12	.03	16%
3. Back and Turn	5.60	36	.16	.04	23%
4. Travel loaded	6.13	35	.17	.03	21%
5. Drop	3.46	38	.09	.04	41%
6. Travel Empty	5.84	35	.09	.02	19%
	28.05				

